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DAVID BEECROFT, *President* COKER F. CLARKSON, *Secretary* C. B. WHITTELSEY, *Treasurer*

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THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. IX July, 1921 No. 1

The Society's Research Program

By President David Beecroft

IT is a welcome opportunity to have the privilege, the honor, to address you as your president, on account of what our Society has accomplished in its brief history of 15 years, and in view of the character of the times through which we are passing and the problems lying ahead with which we must cope. We have passed milestones on the automotive highway but the future is not so clearly defined as we hoped a few years ago it would be; within 12 months we have been brought face to face almost brutally with situations that have been anticipated by few, if any, in the industry. Our concern is with the immediate as well as the more remote future.

Within the last 12 months we have seen waves of industrial depression follow each other in long successive undulations beginning at the Atlantic and ending at the Pacific. We have not only watched these waves traverse the breadth of our land but have seen them pursue their undulatory course across the Americas to the south, across Australia, Africa, Asia and devastated Europe, until we could not locate a single center on the earth's surface that seemed immune from the depression that we are still in the midst of.

Fundamentals

We are not yet through liquidation, and are barely on the threshold of the adjustment period that lies ahead. These are days when courage is needed; when the fiber of which men are made is under test and when integrity and self-reliance are necessary attributes.

This situation has suggested the subject of these remarks, namely, education, a more general consideration of fundamentals and the development of greater self-reliance. In no field of human endeavor are these qualities more essential than in engineering, and this is especially true in a department of engineering such as transportation, which is so interwoven with most of the other industries of the world.

In transportation the automotive engineer must play his rôle and it must be a just and equitable one. He must give to the railroad what it can best do; he must give to the motor truck that which it can transport more economically that other means; to the commercial airplane should go that which belongs to it. There must be no wasting of effort by any form of transportation attempting to take unto itself that which can be more economically performed by another medium of transportation. Corporational selfishness may exhibit itself in transportation and for a short time make headway, but in the end the efficient will triumph; in transportation the straight line, representing the greatest efficiency, will win. Recently the different kinds of transportation were warring among themselves, vainly trying for the victor's share of the spoils, but a change of attitude has been exhibiting itself and now railroads are admitting the right of the motor truck in certain divisions of the transportation world. Let the law be, render unto Cæsar that which is Cæsar's and to God that which is God's.

If the engineer is to maintain the status of his profession, and follow the ideal of seeking after the truth, the pursuit of education must be an ever-present consideration. He must ever breathe the spirit expressed in the words of Ulysses, "To follow knowledge like a sinking star beyond the utmost bound of human thought . . . to sail beyond the sunset and the paths of western stars until I die . . . to strive, to seek, to find, and not to yield. . . ."

For the first time in our industry, since we shed our swaddling garments, we are measuring ourselves with the other automotive manufacturing nations. Before the war we were not an exporting nation, as the factory expansion which gave us the production we have today was developed during the early years of the war. Previous to 1914 our foreign trade was a diversion; today it is a necessity. We find ourselves with factories of greatly expanded capacity, greater capacity than our domestic demands can absorb, and are faced with the alternatives of remaining in and increasing our position in the markets of the world or reducing output and depriving ourselves of the lower production costs we attained by virtue of volume produced. For six years we have been in the markets of the world in a more or less representative way but, lest we forget, let it be recalled that the world markets sought our wares and the world's buyers knocked on our doors; our task was easy—we opened the doors, took the remittances and delivered the merchandise. "Easy come, easy go," is an old proverb, but still applicable. We might also further fortify ourselves by borrowing from Divine Writ words perhaps suitable to our foreign trade situation, namely, "Wherefore let him who thinketh he standeth take heed lest he fall."

[1] Presidential address delivered at the Semi-Annual Meeting of the Society, West Baden, Ind., May 24, 1921.

Perhaps to some engineering and foreign trade may seem far afield, but only last week the president of one of our largest railroad systems in his testimony before the Interstate Commerce Commission attributed the present decline in railroad traffic to the falling off of our foreign trade, which decreased $657,000,000 in three months of 1920 as compared with corresponding months in 1919. Not only has foreign trade affected our railroad systems but it is affecting all industries, and whatever factors affect the industries with which he is connected should properly be a matter of concern to the engineer.

Foreign trade, while directly a merchandizing activity, has a very close connection with engineering, and its future is dependent to no small extent on the knowledge the engineer shall have of the conditions and the character of the people in the countries in which his product must perform. Some four years ago when our export sales departments ruled that the magneto was not necessary equipment because of our developed battery ignition-systems, it was soon learned that conditions in different countries demanded the magneto and those companies that fitted the magneto were well repaid. Other companies which for a time resisted were soon converted. In the end it was an engineering question; while from a merchandizing standpoint the dropping of the magneto seemed desirable in that it facilitated production, yet in long-distance view, which should be the engineering view, the magneto proved desirable. It is because of many situations of this kind that engineering must be more intimately associated with such factory activities as merchandizing and maintenance as well as design and production. The factory engineer becomes immediately a direct party to foreign trade when sales in certain lands are decelerated due to gasoline selling at $1 per gal., or in another country where the tax is $5 per year per hp. Here we get a closeup realization of how interwoven engineering is with merchandizing, and how only the engineer thoroughly familiar with the fields to which his product goes can serve his company best.

The Engineering and the Sales Departments

The engineer has, moreover, not sufficiently weighed the factors involved in domestic trade. Two years ago we had no world competition but today with European nations entering the field and some of them having been actively in it for a year, it is necessary, if we are to retain our position, to give early consideration to this and related questions. To draw a parallel from our domestic field, two of our large farm tractor manufacturers have within the last 30 days concluded that the high cost of fuel in comparison with animal power has been one of the deterrents in the sale of farm tractors. If this becomes a considerable factor at home where fuel is cheap and the machine is marketed at low cost as compared with prices at which it must be sold in foreign fields, how much more of a consideration does it become with $1-per-gal. fuel and machine prices nearly doubled due to freight, insurance, customs and shipping charges? Only one year ago we found serious engineering defects in certain cars in a section of our own country, due to physical characteristics on the Pacific coast. The engineer was ignorant of the facts and, still worse, obstinate in his error. It was the sales end that finally converted the engineer, whereas it is the duty of the engineer to be a guide to the sales department and correct it when necessary. The engineering mind must give consideration to those factors that directly affect his company.

Let us be constantly mindful of the fact that automotive engineering is far from completion. While in the last 30 years, scarcely a generation, we have seen a measure of progress, hardly comprehended today, the goal lies far beyond the distant hills. Education is the greatest need in present-day engineering. In pursuing education along its devious paths we can gain hope and inspiration from Gotthold Ephraim Lessing, the German philosopher who in his Education of the Human Race, in referring to the broad subject of evolution, said, "Go thine inscrutable way, Eternal Providence, only let me not despair in Thee because of this inscrutableness. Let me not despair in Thee even if Thy steps appear to be going back. Is it not true that the shortest line is always straight?"

Education should only begin when college doors close behind us. The man does not truly live who concludes at any time in his life that his education is completed. "Education gives to man nothing he might not educe for himself. It gives him that which he might educe for himself, only easier and quicker. This in the same way that revelation gives nothing to the human species which the human reason left to itself might not attain, only it has given and still gives the important of these things earlier."

Research

The extension of knowledge and securing it more quickly and easily is one of the functions of the Society that your Council has given consideration to since the first of the year and was under consideration last year. In connection with the term research as related to the Society, the dominant thought is the securing of certain knowledge earlier and with less expenditure of effort and with greater conservation of the talent available. Your Council has seen fit, after deliberate and mature study, to push actively the creation of a Research Department that will take its place in the Society activities along with the standardization work. It is impossible to see what development may be ahead and what expenditures this department may require in the next few years, but in magnitude the research organization should exceed that of standardization, and the growth of the department is dependent only on the support it shall receive from the membership.

Let us analyze briefly what the research is as contemplated and what it would mean to the Society and the members:

First, there has been no thought of creating a special research laboratory for the Society in which to carry on experiments necessary in any research; but rather that existing laboratories in the industry and outside of it shall be utilized for such work. The finances of the Society would not permit of creating a special laboratory, and the feasibility of this would be gravely questioned at this time. There is in Government bureaus, such as the Bureau of Standards and the Bureau of Mines, in our college laboratories and in our industrial laboratories, ample equipment for all necessary research, and it would be wasteful to neglect the intelligent use of this.

Second, there has been no thought in the research program of encroaching on what might be termed the secret developments of corporations. There is nothing communistic or flavoring of engineering socialism in the plan. The research program contemplates nothing more than what has been accepted as beneficial cooperation in association of manufacturers. We have for years, even for centuries, considered the industrial associations formerly known as guilds not only desirable but essential for the efficient promotion of trade. We are today accom-

plishing through them results not considered within the pale of possibility a few years ago.

There is nothing in the research planned that usurps programs of the engineer today. There is no thought of extracting the scientific discoveries of one company and distributing them broadcast to the remainder of the industry. The thought is to do the things that have thus far been left undone; to obtain certain knowledge not only more easily but more quickly, and to be more certain of its accuracy.

For our present convenience, we may consider research under three heads or classes:

There is what might be designated explorational research in different fields. This is pure scientific research, largely conducted by individual scientists with the thought of extending the boundaries of human knowledge. It is akin to the work of an explorer starting on a mission of discovery in an unknown field, a case in point being that of the Scandinavian astronomer who has lived in his observation station within the Arctic Circle, where for 20 years he has studied the Aurora Borealis and as a result established certain scientific relationships previously unknown and by virtue of which new ideas so to speak have been brought into the field for intensive study by the scientific and engineering world. With this class of work the Society has little to do. It has not been considered to be one of our major activities. It must be left to the physicist, the mathematician and the general scientist.

Closely related to explorational research is what might be designated intensive research in the fields brought within the ken of engineering by explorational work. Our program should be closely connected with this. It is here that economy of effort is most needed. This intensive research involves cooperation and organization, and the talent used in it can rarely be used in explorational research. An example of research of this kind is that relating to fatigue in metals. This involves an almost endless number of experiments and tests extending over long periods of time and covering a wide range of materials and conditions. Some of our universities have been conducting researches of this character in which tests have been carried on for over a year and are still far from completion. These experiments do not per se give the answer to fatigue but the findings must be interpreted and from the interpretations deductions made so that it will be possible to predict the fatigue resistance of metals. Intensive researches of this and similar character are supported liberally by large industrial corporations which have their own research laboratories and recognize the magnitude and the urgent necessity of the work.

The third kind of research is industrial or development research which for convenience may be designated competitive research among manufacturers in the same field of industry. It is research in which our program has no part. Competitive or development research has to do largely with the design of a part or completed unit or entire vehicle for manufacture or patent protection. This is the research with which many corporations are directly concerned and upon which their laboratories are largely engaged. It is generally carried on behind locked doors on which is the sign, "Positively No Admission." It is the research which provides the manufacturing secrets of a corporation. Our contemplated program leaves this where it is today, solely with the manufacturer where it rightly belongs. Our program does not even hint at unlocking the door or removing the sign. Competitive or development research is and must remain a company activity.

Careful discrimination between this competitive or development research and intensive and explorational research should be kept constantly in mind. Research of the intensive character will tend to increase rather than restrict the possibilities for competitive and development research. As an example, considering the influence of turbulence in connection with the internal-combustion engine, the knowledge of turbulence elevates the standard of practice of the entire industry to a higher and wider level on which each corporation interested has greater possibilities for individual development, patent protection, and the like. It is only by a recognition of this that we will advance in knowledge as the demands of the day require.

Necessity of Cooperation

Research gives to man nothing he might not educe for himself, but it gives it to him more easily and quickly. So with intensive research, the cost is so great and the time needed so long that only by cooperation and organization in the long chain of tests can we secure the knowledge more quickly, easily and cheaply and be able to incorporate the results in industry sooner. Do not forget, art is long and time is fleeting.

One great need today is the training of men competent to carry on the intensive research activities of not only our colleges but of our industries. Our colleges are not graduating enough men of research caliber to meet the situation unless methods of cooperation and organization are used. We must conserve the human material we have available. No persons are more conscious of the shortage of research personnel than our college heads and no one regrets it more than they do. Too frequently the curricula are not conducive to the proper result.

Up to the last few years there has been little thought of cooperation for conservation in college research, and still less thought of cooperation in intensive research in industrial plants. There is today a lack of appreciation of research by not only the engineers but by company executives, and just as our standardization program met with opposition at its inception and still meets with opposition in some quarters, so we can anticipate opposition to our research work until it is more adequately understood. The work will not deprive any engineer of his present work, but enable him to obtain results which otherwise might not be possible. It is going to provide the engineer with an arsenal well stocked with knowledge that will serve him and speed his efforts to better work.

Our Research Committee has had one specific objective in mind, namely, to secure as the director of the research work a man not only competent to carry on intensive research but capable of the more difficult task of correctly interpreting results obtained from such research. There is a lack of uniformity of interpretation of results obtained, with consequent failure to reach conclusions and make correct deductions. In some intensive researches conducted by one engineer certain factors are neglected, so that comparison of results of experimentation covering the same field by other groups of engineers cannot be made. The measure of result that should be achieved from the effort expended is not achieved. The money has been expended; the useful time has been consumed; the human energy has been consumed, but the results are not what they should be. A competent director should, with reasonable cooperation, be able to eliminate such losses. Had we a

surplus of human talent our program for intensive research would scarcely be necessary but with a shortage of available men the need for such cooperative work becomes imperative. In considering our research problem we suggest that the word research be divested of early associations, that your conception of it be revised, and that it be weighed in the light of the work to be done, the end to be accomplished and the tools and personnel available, keeping in mind the differences between intensive and competitive research. Do not forget that the confines of competitive and development research are not to be invaded or molested by our work but that the field for this is to be broadened and lengthened by the intensive-research program contemplated. No time could be more appropriate than the present for the commencement of such work. In times of prosperity, when a company wishes a result along a certain research line, the answer is wanted almost immediately. This is not possible. By beginning now the program will develop with a readjustment of the industry, and some progress will have been made by the time urgent demands are coming in.

There is no thought, in the cooperative intensive-research program outlined, of interfering with or discouraging similar researches by corporations suitably equipped and manned. In the case of similar researches in the electrical and other fields those corporations privately equipped for research have been liberal in contributing their aid and finances for general research. This has a very desirable influence by creating self-reliance on the part of the individual engineer. Those institutions that have made greatest progress in such work have had largely to train their own personnel. Colleges by virtue of their curricula do not make research engineers. Individual training is necessary. Self-reliance is essential. Ability to proceed step-by-step from the known to the unknown is requisite. The French philosopher René Descartes of the sixteenth century gave us a good example of what can be accomplished when self-reliance is developed. In his Discourse on Method in which he laid the foundation work for modern thought and made possible the whole modern philosophic development, he says, "Men should gather the greatest satisfaction from progress made in the search after truth. In the same way I thought that the sciences contained in books, composed as they are of the opinions of many different individuals massed together, are further removed from truth than the simple inferences which a man of good sense using his natural and unprejudiced judgment draws respecting the matters of his experience. . . . The long chain of simple and easy reasonings by which geometers are accustomed to reach the conclusions of their most difficult demonstrations has led me to imagine that all things, to the knowledge of which man is competent, are mutually connected in the same way, and that there is nothing so far removed from us as to be beyond our reach, or so hidden that we cannot discover it, provided only we abstain from accepting the false for the true, and always preserve in our own thoughts the order necessary for the deduction of one truth from another."

Today, as always, the greatest problem in engineering is the engineer. Man dominates here as in all other spheres and only in proportion as the man, tagged as he may be, with the title of engineer, etc., plays his part and considers the attainment of knowledge as the chief end in life, will our industry develop and we reach our full stature and be capable of measuring ourselves successfully with the nations of the world. We have been parties to an industry whose lot has been an easy one. As an industry we have grown by leaps and bounds. Our progress has been comparable with that of an army in the field that has made great gains of territory without adequately consolidating its position as it progressed and suddenly finds itself in an unexpected situation. We have not at all times taken accurate measure of our progress nor taken a sufficiently long-distance survey of the future. We are now at a time when looking ahead is more needed than it has been heretofore. We require better qualifications to cope with the situation at present than were necessary in the past.

EXTENT AND EFFECT OF S. A. E. STANDARDS

WITH the adoption by the Society of the recommendations approved at the May Standards Committee Meeting, the total number of S.A.E. Standards and Recommended Practices will reach 250. The importance of the work represented by these standards can be appreciated more fully by the following analysis of the 224 standards adopted up to April, 1921. If automotive parts, fittings and materials were fabricated in accordance with all the dimensions and analyses specified in the 224 standards, the total number would be 2307. Many of the parts and fittings standards, however, specify dimensions for several parts. For instance, the S.A.E. Standard for Steering-Wheel Hubs specifies dimensions for the steering-column tube, the steering-wheel hub and the steering-wheel-hub nut, three separate parts. If all the parts and fittings were separated into their components, the total number of parts and materials would be 3482.

The accompanying table indicates the manner in which the standards are divided.

It will be noticed that the number of standards adopted for parts and fittings is almost twice as large as for any other group, and that the total number of parts is about four times as large as for any other group. This is because the standardization of parts and fittings affects individual design the least and also because they are, as a rule, commodities sold in the open market.

ANALYSIS OF S. A. E. STANDARDS

Standards	Number of Standards	Number of Sizes and Analyses	Total Number of Parts and Analyses
Powerplant	23	186	447
Electrical Equipment	38	153	204
Parts and Fittings	64	975	1,675
Materials	24	361	368
Transmission	13	225	225
Axle and Wheel	6	45	106
Tire and Rim	15	134	186
Frame and Spring	15	169	185
Control	9	24	43
General	17	35	43
Total	224	2,307	3,482

An analysis of the data showing current practice obtaining at the time of standardizing several parts and materials indicates that the reduction in sizes or analyses averages about 40 per standard and that the ratio of reduction of sizes in current practice to sizes adopted as standard is more than 6 to 1. It follows apparently that standardization of parts and materials reduces the number of sizes and analyses employed in regular production 80 per cent.

Developing a High-Compression Automotive Engine

By Fred C. Ziesenheim[1]

Semi-Annual Meeting Paper *Illustrated with* Charts and Photographs

To facilitate the logical consideration of the development of a high-compression engine for automotive purposes, this paper is divided into parts (*a*) the fuel problem of the automotive industry, (*b*) the selection of the most economical internal-combustion engine for adaptation to automotive purposes and (*c*) the details of the development work undertaken.

The Fuel Problem

The progress of our civilization has been synonymous with the increased use of mechanical power. The sources of energy whence this power is derived are water, coal and petroleum. Of these, petroleum is the most easily produced, transported and converted into power. The conversion of petroleum into power is accomplished most easily and economically by the internal-combustion engine. The importance of the internal-combustion engine can hardly be realized, so recently has it been developed and put to work on the tasks of our civilization. It has become the means of annihilating space on land, in the air and on the sea, and of transportation for more people than any other single agency. Deserts have been watered and made to produce food and the earth now produces food free of toll by animals in return for their energy. At present about 75 per cent of the world's mechanical power is being produced by the internal-combustion engine.

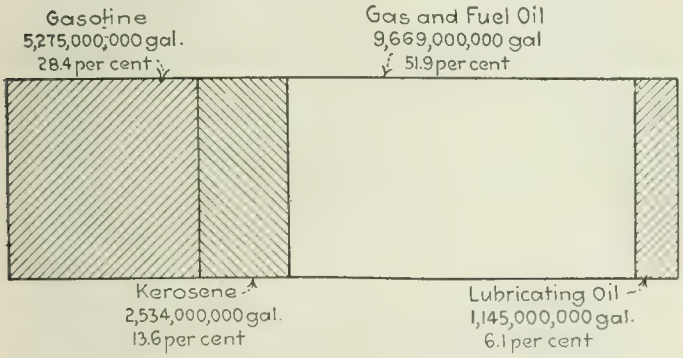

Fig. 1—Estimated Production of Petroleum Products in the United States for 1920

The estimates of geologists and of oil producers as to the petroleum resources of the world show a considerable variance. Even accepting the optimistic view of the oil producers as to the supply available for the future, the necessity for the immediate conservation of this valuable natural resource is strikingly evident. The important products of crude petroleum are gasoline, kerosene and gas, fuel and lubricating oils. The estimated production of the United States for 1920 is given in Fig. 1 and totals 18,623,000,000 gal., an increase of 17.4 per cent over that of 1919. Mexico produced 6,711,600,000 gal. in 1920, an increase of 83.5 per cent over that of the previous year.

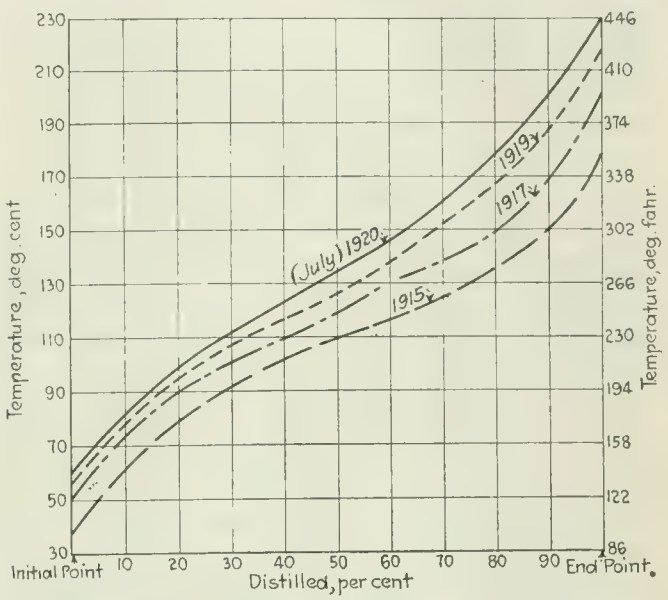

Fig. 2—Trend of the Change in the Volatility of Gasoline from 1915 to 1920 Showing the Rise in the End-Point

The production of crude petroleum, although increasing, is not keeping pace with the consumption of engine fuel. The production of crude petroleum has increased

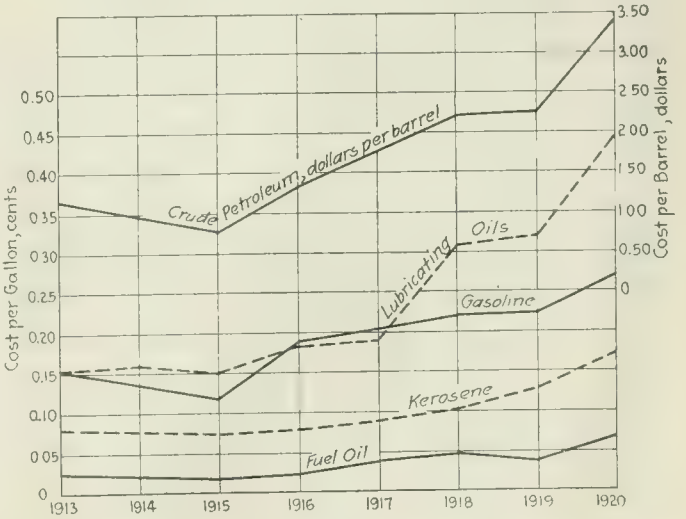

Fig. 3—Average Price of Crude Petroleum and Its Principal Products from 1913 to 1920

[1]M. S. A. E.—Development engineer on high-compression engines, Carnegie Institute of Technology, Pittsburgh.

nearly 100 per cent in the past 10 years; whereas the production of gasoline has increased nearly 600 per cent in the same period. The deficit is being met by constantly lowering the volatility of the fuel supplied. The change in volatility over the period from 1915 to 1920 is shown in Fig. 2, from data of the United States Bureau of Mines. If it is necessary to make additional cuts into the less volatile portions of the crude oil, engine fuel will rapidly become of such a nature that the majority of present-day automotive engines cannot be operated upon it. Ninety per cent of the world is still lighted with kerosene lamps; therefore, the market for kerosene, firmly established previous to the development of the internal-combustion engine, will dispute the priority of the automotive industry to that portion of petroleum products. Fig. 3 shows the average price of crude petroleum and its principal products from 1913 to 1920.

Methods of Increasing the Engine-Fuel Supply

Gasoline substitutes from other sources than petroleum have been suggested, but the quantity of engine fuel required is so enormous that the development of a substitute in the requisite amount must be a matter of many years. The only products of immediate significance are benzol, a by-product in the distillation of coal, and alcohol, made from organic materials. The present total output of benzol is only 2.5 per cent of the country's gasoline requirement. The output, while increasing, is not increasing as rapidly as the consumption of gasoline. By extreme measures, including by-product recovery from all the coal coked, stripping all city gas supplies for light oil and other increases to be expected in the next few years along these lines, we cannot anticipate that much over 5 to 10 per cent of the gasoline demand of today could be met with benzol. The material available for the manufacture of alcohol is unlimited, but the volume of the material required, the investment necessary and the heat required for producing alcohol in quantity, constitute a serious handicap to large-scale production. The present production of alcohol is about the same as that of benzol. The production of alcohol in the tropics has been suggested, but authorities state that it would require 5 acres of tropical vegetation under the most favorable conditions to produce enough fuel to supply a motor truck for 1 year. It is highly improbable that alcohol or benzol can be produced in sufficient quantity in the immediate future to become substitutes for gasoline but, when added to the gasoline supply, they may assist in meeting the situation. Mixing alcohol with gasoline requires the use of a binder to render the two liquids miscible. Benzol is satisfactory for this purpose, about 10 to 15 per cent being required. The amount of alcohol that can be produced for addition to gasoline is limited, therefore, by the supply of benzol available.

The oil shales of the Rocky Mountains, Texas and other districts, hold promise for the future, although the cost of production may exceed that of the present petroleum products. A program for the more economical and efficient utilization of present petroleum resources will be applicable likewise to the shale-oil resources which appear to be the most logical source of supply for the future.

The only commercial method for procuring an engine fuel suitable for use in gasoline engines from kerosene, gas oil or fuel oil is by the pressure-distillation method, commonly called the "cracking" method. Cracking is the most important factor capable of enlarging the supply of gasoline from a given supply of crude petroleum. While cracking processes are legion, very few have attained a working efficiency greater than 40 per cent, thereby entailing a loss of 60 per cent in the process.

The utilization of the fuel-oil portion can be accomplished in two ways. One is to convert it into gasoline through the cracking process, which entails a loss of 60 per cent; the other is to develop an engine capable of operating on fuel oil. To quote J. O. Lewis, chief petroleum technologist of the United States Bureau of Mines:

> Cracking heavy oil into gasoline is an economic loss which should be tolerated only until the problem of a satisfactory automotive engine for consuming the heavy fuels can be solved. In cracking there is both a loss of material and a loss because of manufacturing costs; yet the gasoline resulting yields hardly half the power in the automotive engine of today that the original oil would in a Diesel type of engine.

Commercial cracking processes to date have been able to convert into gasoline only kerosene, gas oil and light fuel oil, leaving the major portion of fuel oil untouched. The gasoline produced by the cracking process is unstable. In time tars are formed which separate out and cause trouble in engine operation.

Characteristics of Present Engine Fuels

Considerable difficulty is being experienced at present in operating automotive engines on the class of fuel supplied. As the volatility of the engine fuel has been lowered, it has become necessary to heat the charge of fuel and air to induce vaporization. Heating the mixture, expanding it, decreases the weight of mixture that the engine can draw into the cylinders, thereby making the engines less efficient. Due to the difficulty of vaporizing the mixture, it will be composed of a liquid portion and a vaporized portion. The liquid portion of the fuel tends to flow along the walls of the intake manifolds, thereby introducing difficulties in the distribution of a uniform mixture to the various cylinders. Some of the liquid portion will not be burned, but drain past the pistons into the crankcase, and cause dilution of the lubricating oil. If injury to the bearing surfaces is to be prevented, the lubricating oil must be drained frequently and replaced with new oil, thereby adding the loss of the lubricating oil to the economic loss of the fuel.

Another characteristic of the present engine fuel is the detonation which occurs unless the compression is kept at a very low figure. Detonation is the term applied to the combustion knock that results with a particular fuel, when its dissociation limit of pressure and temperature are exceeded. The fuel-and-air mixture disintegrates or dissociates, instead of burning freely and quietly, which allows the hydrogen to combine with oxygen and releases free carbon. The almost instantaneous combustion of the hydrogen produces a pressure wave which travels through the gases, impinges on the combustion-chamber walls and produces the familiar knocking or "pinking" called detonation. Detonation may be merely annoying, or destructive, depending on the compression pressure of the engine. The maximum compression pressure allowable must be kept below the point at which detonation occurs.

The conditions which influence the design of gasoline engines, such as the heat required for vaporization, detonation and dilution of the lubricating oil, are present to a greater extent with kerosene as a fuel than with the slightly more volatile gasoline. Kerosene has a higher heating value than gasoline. It is cheaper per gallon and therefore per heat unit but, due to the condi-

tions enumerated, kerosene engines are necessarily designed to operate less economically than gasoline engines.

The brake thermal efficiency of modern automotive engines, exclusive of aircraft engines, which is the percentage of the total heat energy available in the fuel converted into useful work, will be less than 15 per cent under the most favorable conditions of full load and full speed. The limitations imposed by the modern fuel, such as heating of the fuel-and-air mixture and the low compression necessary for obviating detonation, have a tendency to make the thermal efficiency even less than the figure given. An automobile engine under normal running conditions is delivering less than one-third of its full-load power and, due to its method of control by throttling the fuel-and-air mixture, the thermal efficiency will be less than 5 per cent. The important fact to be realized is that the average automobile engine converts but 5 per cent of the energy of the fuel into useful work under the usual running conditions.

Summarizing the fuel problem of the automotive industry, the demand for gasoline has been and is increasing at a greater rate than the production of crude petroleum, which necessitates the lowering of engine-fuel quality by the addition of less volatile portions of the crude. The present engine fuel is unsatisfactory in that it requires heating for vaporization, causes dilution of the lubricating oil and produces detonation during combustion. These are contributory causes for the low thermal efficiency and the operating difficulties of existing automotive engines. The production of gasoline substitutes is insignificant in comparison with the quantity required. If supplementary sources of non-petroleum origin can be developed that are capable of supplying the requisite quantity, it is highly improbable that the product will be sufficiently volatile for the existing types of automotive engine. The conclusions are that conditions in the petroleum industry, the engine conditions imposed by the present engine fuels and the low thermal efficiencies and operating difficulties of modern automotive engines all indicate the advisability of developing another type of engine capable of generating power more economically from less volatile fuels.

Selecting and Adapting the Most Economical Engine

The internal-combustion engine being admittedly superior to other classes of heat engine in the economical generation of power, a survey of the existing types of internal-combustion engine is necessary to select a more economical type of prime-mover for adaptation to automotive purposes. The selection of a type of engine for a particular class of work involves establishing a common basis of comparison. The prime considerations are ability to perform the work and the cost per unit of work.

A device for the accomplishment of a specific task is superior to another capable of doing the same work, when its overall cost of operation is less. The overall cost of operation includes all items chargeable to the device in the fulfillment of its function. These are divided into capital and operating charges, the former being composed of initial, installation, interest, depreciation and insurance costs; and the latter including fuel, lubricating oil, maintenance, attendance and repair expense. Other considerations are ease of operation and maintenance, continuous reliability, the weight of the engine and the fuel, the saving in the space required for the engine and the fuel, safety in operation, cleanliness and the ability to operate on various classes of fuel with a minimum of changes or adjustments. A comparison of the engineering features of the respective types will assist in establishing their relative merits in point of ability and give an indication of their relative costs.

Classification of Internal-Combustion Engines

Internal-combustion engines can be classified, in accordance with the cylinder compression used, as being of low, medium or high compression. The present type of automotive engine is a low-compression engine in which a mixture of fuel and air is drawn from a carbureter into the working cylinder. The charge is compressed to about 40 to 60 lb. per sq. in. and then ignited by an electric spark. This type of engine is apparently incapable of further development to securing greater fuel economy because of limitations imposed by the fuel, as previously stated. Some European developments of the low-compression engine have abolished the curbureter. A French system, the Bellem, injects the kerosene fuel into the combustion-chamber during the end of the compression stroke. At a recent French fuel competition this system, fitted on a Unic five-passenger car weighing 4386 lb. and having an engine of 4-in. bore and 5.9-in. stroke, gave a consumption rate of 17.9 miles per gal. of kerosene. An English engine, the Blackstone, has a low compression of from 80 to 130 lb. per sq. in. and injects kerosene fuel by a puff of compressed air into the combustion-chamber during the end of the compression stroke. At the British tractor trials last year a track-laying Blackstone tractor with a three-cylinder 25-hp. engine had, in the heavy plowing tests, the lowest fuel consumption per acre plowed. In the light-plowing test it was among the first five. However, the development of a kerosene engine offers no appreciable relief from the fuel situation, because the supply of kerosene is even more limited than that of gasoline. An engine developed to use a lower grade of fuel than kerosene, will usually operate successfully on kerosene.

The compression of engines included in the medium-compression class ranges from 100 to 375 lb. per sq. in. These are designated "semi-Diesel," "surface-ignition" or "hot-bulb" engines; all three terms being applied to the same type of engine. The operation of a medium-compression engine is that pure air is compressed in the cylinder and the oil fuel, injected into the combustion-chamber at a definite point in the compression stroke, is usually projected against a hot surface comprising an uncooled portion of the combustion-chamber. The volatile portions of the sprayed fuel are gasified and ignited upon striking the hot surface. The heat supplied jointly by the compression, the hot surface and the early ignition contributes to the vaporization, gasification and ignition of the charge. The combustion is at constant volume, being initiated as an instantaneous explosion, although it continues throughout the working stroke as after-burning, depending upon the characteristics of the engine, the fuel and the load. The pressure-temperature conditions existing when the fuel impinges on the hot ignition surface are such that dissociation occurs immediately, releasing free carbon and the hydrogen which produces the marked detonation of this type of engine. Detonation, which becomes objectionable in low-compression engines with the use of heavier fuels than first-run gasoline, is an inherent characteristic of all medium-compression engines. The detonation can be limited by control of the combustion-chamber temperatures; this is usually effected by water injection. The water, conveyed by the incoming air into the combustion-chamber, must be of sufficient quantity so that the heat required for its vaporiza-

tion will lower the combustion-chamber temperature to the desired maximum and thereby limit the dissociation and detonation that can occur. The heat absorbed by the water is a loss, inasmuch as it is not converted into useful work but is discharged with the exhaust. Medium-compression engines, not equipped with water injection or other satisfactory means of temperature control, are usually given a 20 per cent lower power-rating than engines of similar size that are so equipped. It is often necessary to dispense with the water injection, because the water available contains sulphur, alkali or other elements that are injurious to the cylinder walls.

The advantages of the medium-compression engine as compared with the low-compression type are that

(1) It operates on light fuel oil, distillate, gas oil or kerosene; fuels that are cheaper than gasoline
(2) The fuel consumption is slightly lower at full load and considerably lower at partial loads
(3) It is a simpler engine. The design is usually a two-stroke-cycle, valveless, requiring fewer parts
(4) It has lower operating costs, due to its simplicity and its lower consumption of cheaper fuels

As compared with the high-compression engine, the medium-compression engine is simpler and lighter, and has lower capital and operating costs, in addition to operating on lower compression pressure. The disadvantages of the medium-compression as compared with the low-compression engine are that

(1) It operates on a higher compression pressure
(2) The hot bulb or ignition surface must be heated before starting the engine
(3) It requires water-injection or other means for controlling ignition temperatures
(4) There is difficulty in controlling and maintaining the temperature of the ignition surface for varying conditions of load, for different grades of fuel and for different conditions of cooling and injection water
(5) It has the marked detonation characteristic of all medium-compression surface-ignition engines
(6) Operating troubles result from the nature of the combustion process; that is, dissociation with the release of free carbon, the fouling of the combustion-chamber with carbon and the necessity of cleaning it to prevent preignition. The exhaust is usually black
(7) It has poor speed-regulation with varying load conditions, which is especially objectionable when driving electric generators
(8) High maximum pressure results from early fuel injection

As compared with the high-compression engine, the medium-compression engine has all of the disadvantages in the foregoing list except (7); a higher fuel consumption; an inability to use as low a grade of fuel and therefore a higher operating cost; an inability to use various grades of fuel without major adjustments in the combustion system; and dilution of the lubricating oil.

The principal disadvantages of medium-compression engines are the necessity for preheating the ignition surface before starting; the difficulty in maintaining and controlling the ignition temperatures at all loads; the enormous stresses placed on the mechanism due to the excessively high explosion pressures which result from the necessarily early injection of the fuel; and its inability to operate on other than a narrow range of fuel without extensive changes in the combustion system. These disadvantages are fundamentally inherent in this type of engine and are such as to eliminate the medium-compression engine from consideration as a development for automotive purposes.

The high-compression oil engine produces power more economically than any other known type of heat engine. For comparison with a steam engine using fuel oil, George Otis Smith, director of the United States Geological Survey, states that

> The very facts that support the argument for the marine use of fuel oil, the greater efficiency and economy of space and labor, can be cited in favor of the internal-combustion engine of the Diesel type against the steam engine. The increased thermal efficiency of the new engine, with its resulting addition to available cargo space or to cruising radius, is more than 2½ times that of the steam engine. The experience of the Bethlehem Steel Co. is that its new oil-engine ore carrier, the Cubore, in continuous service between Cuba and Sparrows Point, Md., uses only 36.7 per cent of the fuel oil consumed by a sister ship differing only in that it has the most modern type of steam plant. The tremendous economy thus possible in the marine consumption of fuel oil demands the immediate adoption of internal-combustion engines if the world wants to make the largest use of its oil resources for the longest time.

In a paper entitled Working Processes of Internal-Combustion Engines[2] which was presented at the 1919 Semi-Annual Meeting of the Society, Prof. C. A. Norman of the Ohio State University stated that

> An investigation by the United States Department of Agriculture reveals the fact that 68 per cent of all tractor-engine troubles occur in the magneto, spark-plugs and carbureters or in the accessories of the present-day automobile engine. Bearings, cylinders, piston-rings, valves and springs, lubrication and starting systems, that is to say, the parts common to all classes of combustion engines, gives rise to only 32 per cent of the troubles. From the point of reliability alone we have then a most serious reason to be on the lookout for some new type of automotive engine.
>
> The reason from the point of view of fuel utilization is even more compelling. An engine may be considered as having good carburetion that turns into shaft horsepower more than one-fifth of the fuel supplied it. Four-fifths is regularly wasted in our present automotive engines. Yet the fuel must be a particularly high grade one, a liquid meeting severe requirements of volatility, liquidity and the like. The question of a continued supply of such a fuel is becoming a serious one. . . . Actually, Diesel engines with compressions as high as 550 lb. per sq. in. have, on the test stand, reached utilizations of 36 per cent.

In the operation of a high-compression oil engine, pure air is compressed in the engine cylinder to a pressure of from 350 to 500 lb. per sq. in. The temperature attained by the air, due to its compression, is from 950 to 1100 deg. fahr., as is shown in Fig. 4. The oil fuel is injected in a finely divided state into the highly compressed air of the combustion-chamber, commencing just previous to the moment when the piston reaches the top dead-center. The injection is continued for a specific period, depending upon the engine load. Auto-ignition of the injected fuel takes place, due to the temperature of the air compressed within the cylinder. The combustion which ensues is slow burning; the rate of fuel injection is such that the combustion takes places at constant pressure. The combustion of the fuel releases heat and does expansive work on the piston, thereby converting the heat energy of the fuel into mechanical work. The engine cylinder is scavenged free of combustion

[2]See THE JOURNAL, July, 1919, p. 3.

gases and filled with pure air, and the operating cycle is then repeated.

The advantages of the high-compression engine as compared with engines of low and medium-compression are that it has

(1) Unsurpassed fuel economy and high thermal efficiency, irrespective of the size of the engine
(2) Ability to maintain its economy and thermal efficiency for fractional as well as full loads
(3) Ability to operate successfully on non-volatile fuels, heavier and cheaper than gasoline or kerosene; in fact, on any hydrocarbon fuel that can be rendered liquid
(4) Freedom from the occurrence of detonation
(5) Complete and clean combustion of the fuel, with a clear exhaust
(6) High torque characteristics at speeds lower than those of normal rating
(7) Easy instantaneous starting, with a rapid assumption of full load
(8) Excellent speed regulation throughout its speed and load range
(9) A greater possible simplicity of design
(10) No water-injection or other devices for the control of combustion-chamber temperature
(11) Absence of the fuel-distribution problem of the low-compression engine
(12) No lubricating-oil dilution as in both the low and the medium-compression engines
(13) Ease and simplicity of operation
(14) Reliability and low operating costs
(15) Increased safety in operation from the use of a less volatile fuel of high flash-point

As compared with low and medium-compression engines, the disadvantages of the high compression engine are the

(1) Heavy construction, necessitated by high compression
(2) Difficulty of maintaining high compression under long-sustained service
(3) Requirement of higher capital costs for the heavy construction
(4) Requirement of a higher initial cost necessitated by the excellence of the materials and workmanship
(5) Higher initial cost resulting from the greater ability and amount of work required in the development of the engine.
(6) Educational work necessary for the operation and servicing of a new type of engine

The steps in the complete combustion of a liquid fuel in a high-compression internal-combustion engine are the pulverization of the liquid fuel into fine particles; the vaporization or gasification of the fuel particles; the intermixture of the gasified fuel and oxygen; the decomposition and recombination of the fuel gases with oxygen; and the combustion with an attendant release of heat.

Pulverization, being the initial step, is the predominant one in achieving complete combustion. The manner and effectiveness of the other steps in fulfilling their functions are determined by the extent to which atomization is achieved by the pulverization. The conditions for optimum pulverization are (*a*) an instantaneous pulverization of the fuel upon its initial discharge into the combustion-chamber, with no dribble at the beginning of the discharge; (*b*) a maximum pulverization of the fuel, the ideal condition being complete atomization and that the fuel be so finely divided that the particles are without finite mass; (*c*) uniformity of pulverization throughout the period of discharge irrespective of the rate of discharge, which may vary within narrow limits; and (*d*) uniform maximum pulverization of the fuel up to the moment of cessation of discharge, with a clean complete cut-off of the fuel and no after-dripping. High-compression engines can then be compared on the basis of the means and the extent to which pulverization and consequently combustion are achieved.

High-compression engines are classified, as to their method of injecting the fuel into the combustion-chamber, into the three general classes of air, gas-pressure and mechanical injection.

Air Injection

In the air-injection method the fuel is injected into the combustion-chamber by highly compressed air at a pressure exceeding that of the cylinder by from 200 to

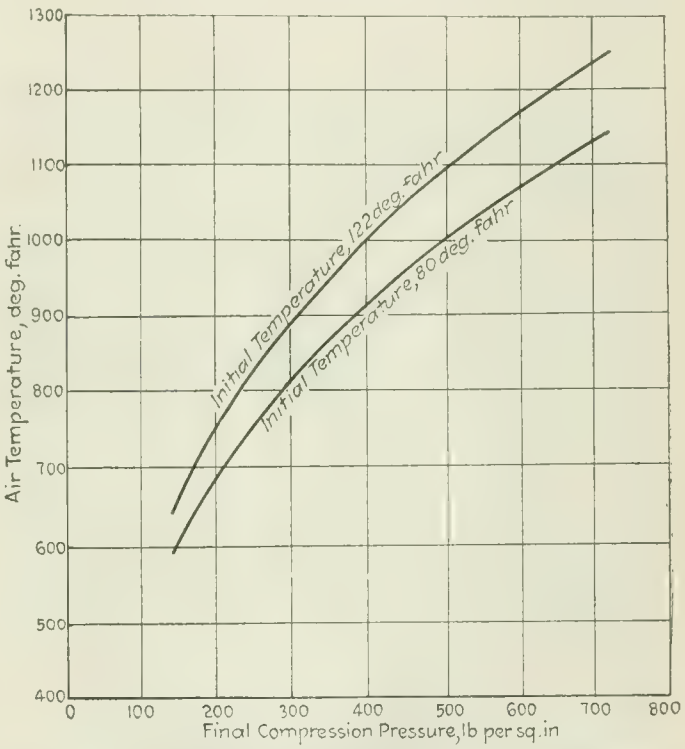

Fig. 4—Air Temperatures for Different Final Compression Pressures

600 lb. per sq. in. The Diesel engine, which uses air-injection of the fuel, is the original high-compression engine and has undergone a consistent development during the 28 years since its invention by the German engineer, Dr. Rudolph Diesel. The Diesel engine has been adapted to practically every class of prime-mover. It has been built in sizes of cylinder of from 2 to 2000 hp. The largest marine engine totals about 6000 hp.

As shown in Fig. 5, the Diesel engine requires a multi-stage air compressor for delivering the injection air at a pressure of 800 to 1200 lb. per sq. in. Fig. 6 shows a sectional view of a Diesel-engine fuel-injection valve. The interior of the fuel-valve, being in communication with the air-compressor, is filled with air at a pressure of from 800 to 1200 lb. per sq. in. The oil fuel, pumped against the air pressure existing in the injection-valve, is delivered into the lower portion of the chamber surrounding the valve-stem. The quantity of fuel delivered is regulated by a governor to conform with the engine load. When the valve-stem is lifted by a cam acting through levers, the air forces the fuel through the pulverizer into the combustion-chamber. The pulverizer

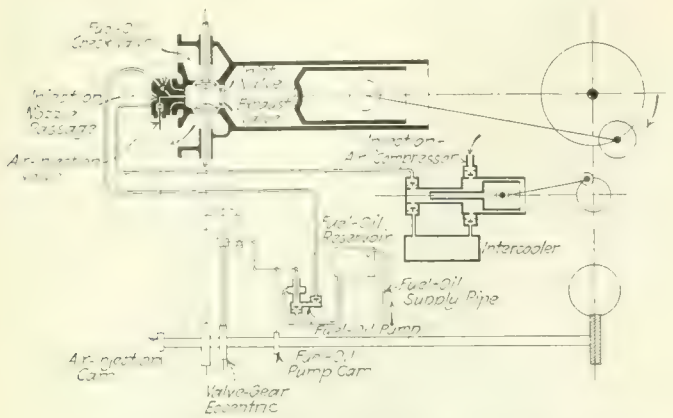

FIG. 1.—DIAGRAMMATIC ARRANGEMENT OF THE DIESEL ENGINE MECHANISM

forms a labyrinth passage for distributing and intimately mixing the fuel with the injection air. The injection air, expanding from its pressure of from 800 to 1200 lb. per sq. in. to the 500 lb. per sq. in. pressure of the combustion-chamber, breaks up the fuel into a fine spray. The combustion-chamber air is at a temperature of about 1100 deg. fahr., due to its pressure, which causes auto-ignition and combustion of the fuel particles. The combustion releases heat and does expansive work on the piston. The distribution of the fuel charge throughout the combustion-chamber and the intermixture of the gasified fuel and oxygen are greatly facilitated in the Diesel engines through the turbulence created by the discharge and expansion of the injection air.

As compared with other types of high-compression engine, the advantages of the Diesel engine are that the expansion of the injection air is an effective method of achieving pulverization of the fuel; the injection air, usually 25 times the volume of the fuel, supplies oxygen for combustion; and the injection air produces a turbulence, not duplicatable easily by other known means, which materially aids in the distribution and intermixture of the gasified fuel and oxygen. Due to the long development of the Diesel engine, sufficient data are now available for designing injection valves to meet particular conditions of fuel, load and other requirements, provided these conditions do not differ materially from those already met in practice. The influence is now known of

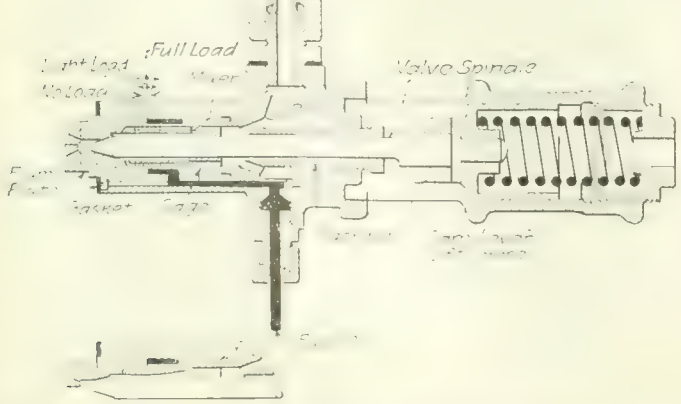

FIG. 2.—SECTIONAL VIEW OF A DIESEL-ENGINE FUEL-INJECTION VALVE

pulverizers, valve-lift and orifices, upon atomization, the rate of combustion and the form of the indicator diagram. The disadvantages of the Diesel engine, as compared with the other types of high-compression engine, consist of the complication of the air-compressor which generates the high-pressure injection-air; the higher initial costs and capital charges necessitated by the air-compressor; and the operating difficulties incident to the use of the air-compressor as the majority of Diesel-engine troubles are attributable to the air-compressor and its accessories. Operating difficulties result in lessened reliability and are a source of operating expense.

The air-compressor comprises the usual mechanical parts such as pistons, connecting-rods and valves. The compressor must be of not less than three stages and proportioned so that no undue ratio of compression and consequent temperature can occur in any one stage. Increases in the air temperature which occur with compression must be reduced by intercoolers between each stage and by an aftercooler to reduce the final temperature to atmospheric temperature. Air-compressor valves are a fruitful source of trouble and must be removed at frequent intervals for inspection and cleaning. Air-receivers must be provided for storage and pressure equalization. Moisture that collects in the air-receivers must be drained at regular intervals. Lubrication of the air-compressor is particularly difficult, due not only to the high temperatures encountered, but to the danger of charging the air-receivers with an explosive oil-vapor. Disaster from this source is all too frequent.

Further disadvantages of the Diesel engine are that the power required to drive the air-compressor, usually taken as from 10 to 16 per cent of the engine rating, causes a lower mechanical efficiency and therefore a lower thermal efficiency since there is a less economical utilization of the fuel supplied. In addition, the expansion of the injection air in the combustion-chamber with the consequent absorption of heat, causes a refrigerating effect. To counteract this heat loss, a higher initial compression-pressure is necessary for obtaining the requisite temperature for ignition. The higher compression-pressure implies a lower mechanical efficiency, a heavier and more expensive construction, and an added difficulty in maintaining the higher compression-pressure under long service. The satisfactory operation of a Diesel engine requires complete combustion of the fuel. It is therefore essential that three quantities which influence combustion be varied in conformity with the variable conditions of speed and load imposed on the engine. The quantities are the quantity of fuel per charge, the quantity of injection air per charge and the fuel-valve lift and period of opening per charge. The usual practice is to vary the quantity of fuel per charge only. The quantity of injection air per charge is controlled only in a general way by the variation of the injection-air pressure through hand manipulation of an air-compressor regulating-valve, usually when the changed conditions are to remain for some time. Extended operation under no-load or light-load conditions is possible only with a diminution in the pressure of the injection air from that used at full load. The gear necessary for varying all three is necessarily very complicated and has been installed only on German submarine engines, where operators capable of maintaining the equipment are in constant attendance. In an engine designed for variable load and speed conditions such as are encountered in automotive service, it is essential that the quantities enumerated be varied by a suitable gear to conform with load and speed conditions. The

complication of such a gear renders the design impracticable.

Gas-Pressure Injection

In the gas-pressure method of injection the fuel flows or is injected into an auxiliary chamber which is in communication with the combustion-chamber. During the compression of the cylinder air a portion of the fuel within the auxiliary chamber is vaporized and burns, the resulting gas pressure within the auxiliary chamber forcing the fuel through small orifices into the combustion-chamber.

An example of gas-pressure injection is found in the

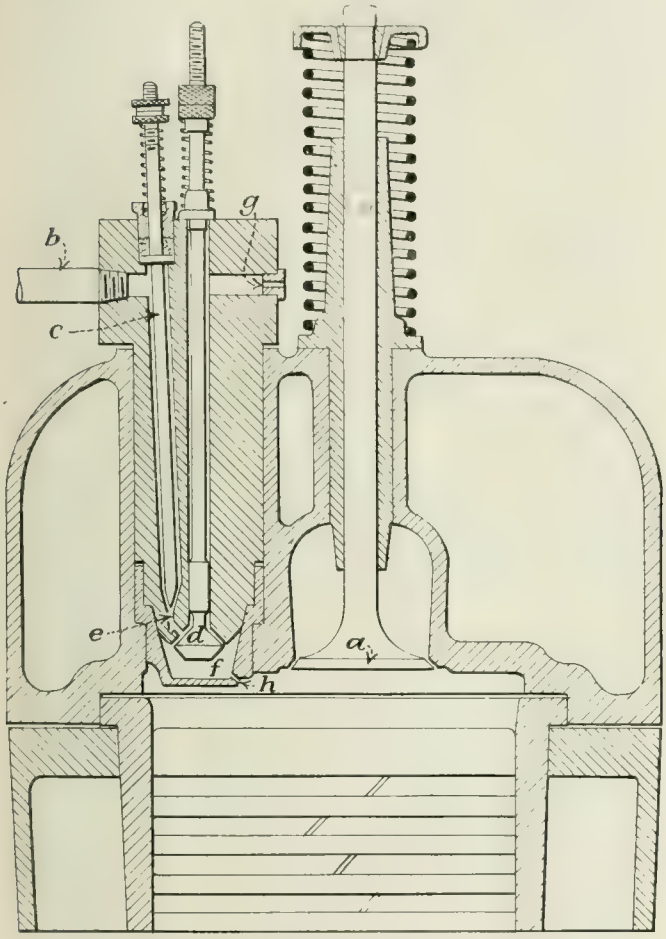

Fig. 7—Gas-Pressure-Injection System of the Hvid High-Compression Oil Engine

Brons or Hvid high-compression oil-engine, illustrated in Fig. 7. The Brons engine is the original Dutch development. It is called the Hvid engine in this country from the name of the American patentee. The engine operates on the four-stroke cycle. On the suction stroke pure air is drawn into the combustion-chamber through the air intake valve *a*. The fuel supply pipe *b* supplies fuel to the chamber about the metering-pin *c* by gravity feed. During the greater part of the suction stroke the fuel-valve *d*, held open mechanically in conjunction with the air-intake valve *a*, permits the fuel to flow through the fuel-admission hole *e* into the fuel-injection cup *f* along with a small amount of air, which enters through the small opening *g* past the fluted stem of the fuel-valve *d*. The quantity of fuel admitted is regulated by the metering-pin *c*, which is in turn controlled by a governor. The air-valve *a* is closed at the end of the suction stroke. The fuel-valve *d* also is closed, covering the fuel-admission hole *e*. During the compression stroke all valves are closed and the air is compressed to 500 or 550 lb. per sq. in., thereby increasing its temperature to 1000 deg. fahr. Compressed air enters the injection cup *f*, through the small injection orifices at *h*, until the pressures are equalized. The pressure-temperature conditions within the cup are now most favorable for distilling off the lighter and more volatile components of the oil fuel. The fuel vapors ignite, due to the temperature existing, and the resulting high pressure within the cup forces the rest of the fuel out in a finely divided state, through the small orifices at *h*, into the air of the combustion-chamber. The pulverized fuel is vaporized and ignited by the temperature of the compression, and combustion takes place. The combustion releases heat and the expansion of the gases forces the piston out on its working stroke. As in any four-stroke cycle during the exhaust stroke, the exhaust-valve opens and the products of combustion are driven out by the piston. The Brons engine can be operated on the two-stroke cycle by mechanically injecting the fuel into the injection cup.

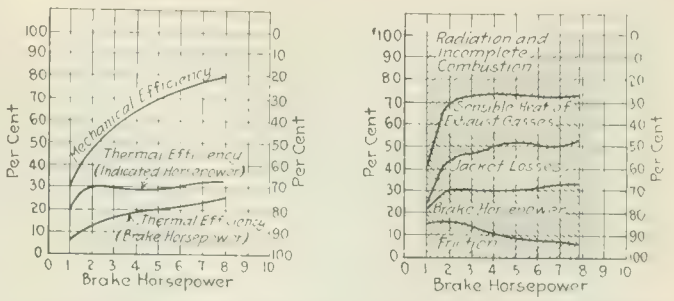

Fig. 8—Heat-Balance and Efficiency Curves for an 8-Hp. Single-Cylinder Farm Type Engine Operating on the Hvid Principle

Sears Roebuck & Co. have successfully marketed a series of horizontal, single-cylinder, farm-type engines which operate on the Brons principle. In Fig. 8 heat balance and efficiency curves are shown of one of their 8-hp. engines. Fig. 9 gives a comparison of the fuel consumption of this engine with that of a similar low-com-

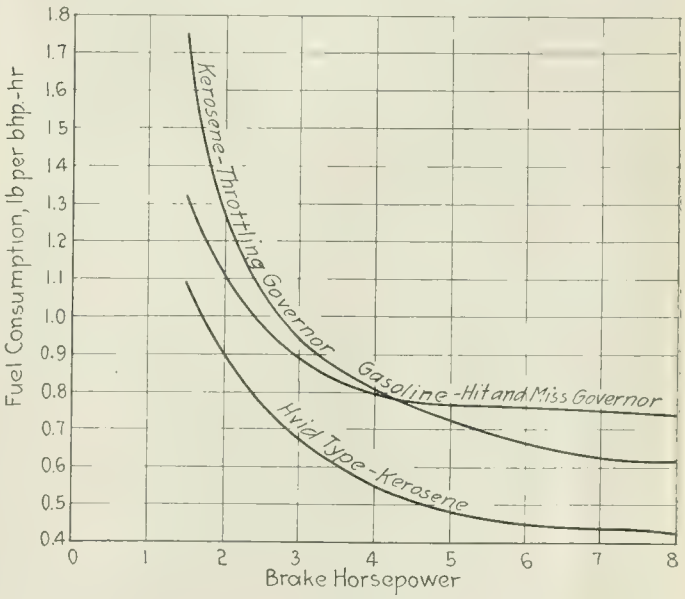

Fig. 9—Curves Showing the Comparative Fuel Consumption of an 8-Hp. High-Compression Engine and a Similar Low-Compression Engine

TABLE 1—PRICES OF SEARS ROEBUCK & CO. ENGINES DURING 1921

Brake Horse-power	Selling Price	Weight, lb.	Bore, in.	Stroke, in.	Cost per b.h.p.	Cost per lb.
Brons-Hvid Engines						
1½	$105.00	323	3	4½	$70.00	$0.325
3	155.00	615	3⅞	5½	51.66	0.252
6	260.00	1,100	5	7½	43.33	0.236
8	309.00	1,500	5¾	9	38.63	0.206
Average					50.90	0.259
Gasoline Engines						
1½	57.75	246	3¼	5	38.50	0.234
2½	93.50	483	4	6	37.40	0.193
5	136.00	777	5	7½	27.20	0.175
7	191.85	1,107	5¾	9	27.40	0.173
9	291.00	1,823	6½	11	32.33	0.159
12	365.00	2,433	7½	12	30.41	0.150
Average					27.64	0.180
Percentage of Greater Cost of Brons-Hvid over Gasoline Engines						
Prices for 1921					84.1	43.8
Prices for 1920					22.5	14.6

pression engine. Table 1 gives a comparison of their selling prices for Brons engines and for gasoline engines. The Brons engines are sold on the basis of their greater fuel economy, about 45,000 hp. being sold per year.

The success achieved by the Brons engines of Sears Roebuck & Co. can be attributed to the almost exclusive use of kerosene as fuel; the low loads imposed on the engines in farm service and the fact that the engines are usually operated at considerably less than their full-load rating; the low load factor as the engines are run but a few hours at a time and only a few days per week; and the elimination of crankcase dilution of the lubricating oil by the use of horizontal single-cylinder open-crankcase engines lubricated by oil-cups and grease-cups.

The Pittsburgh Filter & Engineering Co., located at Oil City, Pa., developed a Brons-Hvid engine which has given satisfactory service for over a year in supplying electrical power to its machine shop. The engine is a four-cylinder, vertical marine type, of 8½-in. bore and 12-in. stroke, rated at 100 b.hp. at 400 r.p.m. Under favorable conditions, the fuel consumption is 0.45 lb. per b.hp-hr., the fuel used at present is a Pennsylvania fuel oil of 28 to 42 Baumé gravity. Western fuel oils and kerosene are also satisfactory fuels. Aside from cleaning the injection cups occasionally, the engine requires no frequent servicing. There is no appreciable carbon deposit on the combustion-chamber parts. The piston does not appear to attain as high a temperature as in a Diesel engine. Crankcase dilution from fuel that escapes past the pistons requires that the lubricating oil be renewed occasionally. The exhaust is clear in color, showing only a very slight blue haze. More than 1½ years of experimental work was required on the proportions of the injection cup before the present satisfactory operation was attained. The data acquired by this laborious process are of very little use in constructing an engine of different cylinder volume or other considerable variance in conditions.

Claims are made for the Brons-Hvid engines that they possess all the advantages of the Diesel engine without the Diesel engine's principal disadvantage, the air-compressor. It is unquestionably the simplest high-compression engine to date; it will start and run on any free-flowing oil; its fuel consumption compares favorably with that of the Diesel; and it has remarkable "bulldog" torque characteristics. Speeds of 1800 r.p.m. have been attained in experimental engines. Although the Brons-Hvid engine has been in existence nearly as long as the Diesel engine, it has achieved no success in Europe or America, except as distributed by Sears Roebuck & Co., as already stated. One of the objections urged against it is that the gas-pressure injection system, being entirely self-contained and automatic in operation, requires an exact relation in the proportions of the injection cup. A cup developed by long tedious cut-and-try methods until satisfactory for particular fuel, load, speed and engine conditions, will not operate satisfactorily with any considerable change of these conditions; nor are the data secured applicable to designing for different conditions.

The ideal conditions for the complete pulverization of the fuel cannot be attained in the Brons engine. This implies incomplete combustion with its attendant difficulties such as high explosion pressures; fouling of the combustion-chamber with the formation of carbon; and after-burning or delayed combustion with pitting of the exhaust-valves. A small quantity of fuel can be drawn from the injection cup into the combustion-chamber during the suction stroke. Some of this fuel will drain past the piston into the crankcase, causing a serious contamination and dilution of the lubricating oil with attendant ill effects on engine operation. Soft gummy carbon deposits are formed on the piston skirt, necessitating the removal of the piston for cleaning at regular intervals. Fuel remaining on top of the piston, instead of draining into the crankcase, will, during the compression, be "cracked" into hydrogen and free carbon. The hydrogen and other volatile constituents will ignite prematurely, causing excessive explosion-pressures which may range as high as 900 lb. per sq. in. An engine attaining such high explosion pressures must be made of heavier construction than one operating on the slow-burning or constant-pressure cycle.

The carbon accumulation may become so serious that the engine has to be dismantled to permit its removal. In some engines of this type there is no appreciable carbon accumulation. Poor speed and load regulation is an operating disadvantage of the Brons engine for many classes of service. The cutting off of the fuel supply by the metering-pin is not effective until after several charges have been discharged and burned. In starting or under sudden overload, partial charges may accumulate in the injection cup and, when discharged, will produce an excessive pressure that may result in completely wrecking the engine.

The Steinbecker engine,[3] which is a German gas-pressure-injection engine, has an auxiliary chamber, similar to an inverted bottle, which is in communication with the combustion-chamber. During the compression of pure air to 425 lb. per sq. in., a pump introduces some fuel into the neck of the chamber. The fuel is conveyed into the auxiliary chamber by the compressed air, which attempts to bring about an equalization of the pressure in the combustion and auxiliary chambers. The pressure-temperature conditions within the auxiliary chamber are such as to cause ignition of the fuel's volatile constituents. The gas pressure, resulting from this combustion in the auxiliary chamber, causes a reversal in the direction of the gases back into the combustion-chamber proper. The fuel, as it is introduced into the neck of the auxiliary chamber, is driven into the combustion-

[3]For a complete description of this engine see *Automotive Industries*, March 3, 1921; p. 501.

chamber in a finely divided state and is available for the combustion. The advantages claimed for the Steinbecker engine are similar to those claimed for the Brons, but the engine is considerably more complicated. Its disadvantages are, first, that an additional fuel is necessary for starting. In starting the engine, a very volatile fuel is injected by a special pump into the auxiliary-chamber throat; its combustion soon brings the chamber to a temperature that will cause ignition of the heavier fuel, whereupon the additional pump is cut out of operation. The main-pump plunger is immediately withdrawn upon completion of its stroke, thereby withdrawing the fuel in the discharge line and preventing an "after-drip" of fuel from the injection device. Second, there is difficulty in temperature control of the ignition chamber. In common with the Brons engine, the proportioning and temperature control of the ignition chamber for satisfactory operation under particular conditions as to fuel, load, speed and engine characteristics, can be arrived at only by long cut-and-try methods. Any considerable change in the conditions renders satisfactory operation impossible. Inasmuch as the operation of the Steinbecker automatic-injection process involves so many variables that are difficult to control, the engine must show satisfactory and consistent performance in actual service before it can be accepted as a successful design. The engine has undergone 7 years of experimental work and is now presumably ready for manufacture.

Mechanical Injection

When mechanical injection is utilized, the fuel is injected into the combustion-chamber by virtue of its own pressure produced by a mechanical pump. This type of engine offers a particularly attractive field for development in that it can utilize the same low-grade fuels as the Diesel engine, it can achieve as good if not better fuel economy and it can do this with a much simpler mechanism.

British firms have taken the initiative in developing this type of engine. Vickers, Ltd., has supplied most of the British submarines with mechanical-injection engines, and this company has gone extensively into the manufacture of engines of this class for merchant ships. It is stated that this type of marine engine totals over 500,000 hp. The recent motor-tanker Narragansett of the Anglo-American Oil Co. was fitted with two Vickers engines of 1250 b.hp. each. The engines are of the six-

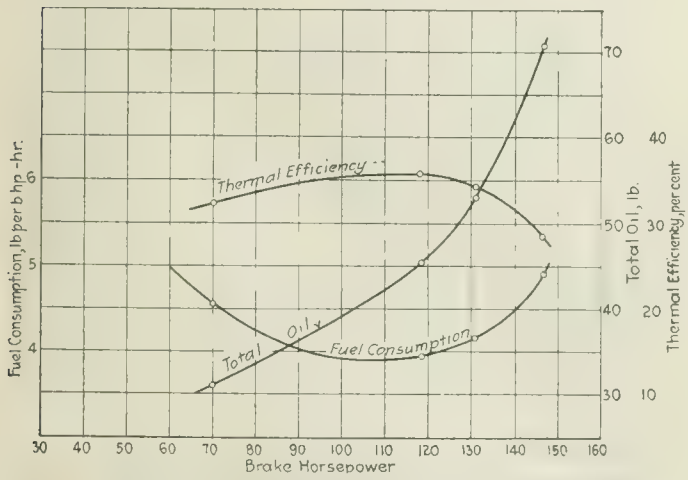
Fuel Consumption, lb per b hp -hr.
Thermal Efficiency
Total Oil
Fuel Consumption
Total Oil, lb.
Thermal Efficiency, per cent
Brake Horsepower
30 40 50 60 70 80 90 100 110 120 130 140 150 160
4 5 6
30 40 50 60 70
10 20 30 40

Fig. 10—Thermal Efficiency and Fuel-Consumption Curves of a Horizontal Four-Stroke-Cycle Engine for Stationary Power-Plant Use

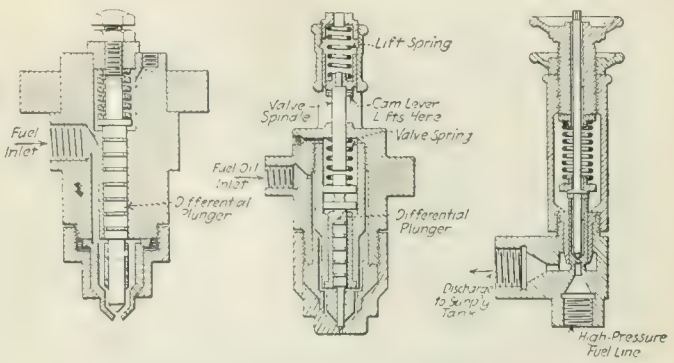

Fig. 11—Three Types of Valves

The Injection Valve at the Left Is Controlled by the Fuel-Pressure Difference and That in the Middle Has the Fuel Opening Controlled Mechanically by a Cam and a Lever. The Valve at the Right Is a Pressure-Regulating Valve.

cylinder, four-stroke-cycle crosshead type, with 24⅛-in. bore and 39-in. stroke, having a normal speed of 118 r.p.m. Their operation is that the fuel oil, which has been thoroughly cleaned of all grit by strainers, is delivered by a four-throw pump into a main pipe which supplies all the injection valves. The pump is arranged to maintain the fuel at a pressure of from 4000 to 4500 lb. per sq. in. The fuel-injection valve is mounted in the cylinder-head and consists of a spring-loaded miter-valve and stem. The stem is mechanically lifted by a cam and lever to permit the fuel to discharge into a small spherical chamber. The spherical chamber is provided with five holes 0.019 in. in diameter. The fuel, due to the pressure difference existing between it and the air of the combustion-chamber, flows into the spherical chamber when the valve stem is lifted, and is discharged through the small holes into the combustion-chamber as a fine spray. The temperature resulting from the 430-lb. per sq. in. compression, about 1000 deg. fahr., is sufficient to cause ignition and consequently combustion of the injected fuel. The time of injection and its period or duration can be varied in conformity with the engine load. The fuel consumption claimed for the Vickers engine is 0.381 lb. per b.hp-hr., but the engines of the Narragansett averaged 0.42 lb. per b.hp-hr. under the service conditions of a trial run. This figure is equal to that of the best Diesel engines.

Ruston & Hornsby, Ltd. builds a line of horizontal four-stroke-cycle engines suitable for stationary powerplant use. The line comprises 11 single-cylinder engines ranging from 15 to 170 b.hp. and twin-cylinder engines of from 100 to 340 b.hp. For burning the lowest grades of tar oil, it is necessary to inject a small quantity of a more inflammable fuel just prior to the main charge to insure ignition. This pilot charge, as it is termed, amounts to but 5 per cent of the total fuel used at full load. The injection-valve is not mechanically operated, as in the Vickers engine, but is actuated hydraulically by the pressure imposed on the fuel by the fuel-pump. The injection-valve for both pilot and main charges consists essentially of two spring-loaded differential pistons which uncover their valve-seats when the pressure of the fuel exceeds the resistance of the springs. The timing and duration of the valve-opening, the pressure and rate at which the fuel is injected and the quantity injected, are dependent upon the action of the fuel-pump and the governor. The fuel-pump action is influenced by the governor and by the timing and rate of motion imparted to the pump plungers by their driving cams. The governor controls a bypass valve which regu-

lates the quantity of fuel pumped per stroke. Fig. 10 shows the remarkable thermal efficiency and low fuel consumption of one of these engines. A characteristic of this type is that the thermal efficiency and fuel consumption remain fairly constant over a considerable range of load. An injection-valve, operating by fuel-pressure difference, is shown at the left of Fig. 11.

Crossley Brothers, Ltd., builds a series of horizontal single and double-cylinder stationary engines similar to those made by Ruston & Hornsby, Ltd. The engines will burn kerosene, fuel oils and tar oils. Their fuel consumption and thermal efficiency are approximately the same as those of the Ruston & Hornsby engines.

Only two prominent American firms have been building mechanical-injection engines for any length of time. Both engines are based on the same design and have given satisfactory operation in service. The De La Vergne Machine Co., which has been successfully constructing Diesel and hot-bulb engines for the last 26 years, has recently developed mechanical-injection engines of both the vertical marine and horizontal stationary types. The engine operates on the four-stroke cycle. Pure air is drawn into the cylinder on the suction stroke; the air is compressed to a pressure of 330 lb. per sq. in. on the compression stroke. At about 17 deg. of crank travel before the end of the compression stroke, the fuel is injected into the combustion-chamber through two injection-valves that are fitted on opposite sides of the combustion-chamber. The combustion-chamber is in the form of two half-cones with their bases fitted together. The injection-valves are located at the apex of each cone and therefore are opposite each other and discharge toward the common center, which is at the bases of the cones. The fuel, at a pressure of from 1500 to 2000 lb. per sq. in. produced by a cam-operated pump, causes the two spring-loaded injection-valves to open. The injected fuel, being in a finely divided state, is ignited by the heat of compression. Due to the early fuel injection, the initial combustion occurs at constant volume, the pressure rising from that of the compression to 500 to 550 lb. per sq. in. Additional combustion then occurs at constant pressure, as in the Diesel engine. The expansion and the exhaust strokes are completed in the usual manner. The use of the two injection-valves and the peculiar form of combustion-chamber, which is a distinctive feature of oil engines designed by the late William T. Price, is considered advantageous in the atomization of the fuel and in the creation of additional turbulence in the combustion-chamber. The combination of the Otto and the Diesel cycles with combustion at both constant volume and constant pressure is a characteristic of most mechanical-injection high-compression engines and has been termed the "dual combustion cycle." A pressure-volume card is shown in Fig. 12. The Blackstone engine mentioned under low-compression engines also operates on the dual combustion cycle.

Table 2 gives fuel-consumption data obtained in a test of a De La Vergne Type S-I horizontal two-cylinder four-stroke mechanical-injection engine of 17-in. bore and 27.5-in. stroke, rated at 200 hp. at 200 r.p.m. The compression-pressure of cylinder No. 1 was 322 lb. per sq. in. and that of cylinder No. 2 was 318 lb. per sq. in. The maximum pressure at full load was 540 lb. per sq. in. for cylinder No. 1 and 545 for cylinder No. 2. The test was made on Oct. 5, 1920. Fuel oil of 24-deg. Baumé gravity was used. It is stated that the engine will carry 25-per cent overload with no trace of smoke or color in the exhaust; at 30-per cent overload the exhaust begins to become smoky. The fuel consumption obtained compares favorably with that of a Diesel engine.

Table 2—De La Vergne Type S-I Engine Test

Rated Load, per cent	Brake Horsepower	Fuel Consumption, lb. per b.hp.	Engine Speed, r.p.m.
100	200	0.420	200
110	220	0.421	200
75	151	0.410	202
50	101	0.438	204

Although this firm had an established line of Diesel engines, these were discontinued and the building of mechanical-injection engines was undertaken. This was because the latter have, in addition to the advantages of the Diesel engine, such as low fuel-consumption with a wide range of fuels and loads, immediate starting and no standby losses, an inherent advantage of simplicity resulting from the elimination of the air-compressor and air-injection apparatus.

The Ingersoll-Rand Co. is the sales agent for the Price-Rathbun engines which, having the Price injection and combustion system, possess many features in common with the De La Vergne engines, and naturally the same advantages are claimed. The type developed is a vertical four-stroke cycle, which is adapted to either marine or stationary service. The fuel-consumption guarantee is the same as that of the De La Vergne Co., namely, 0.45 lb. per b.hp-hr.

As compared with other high-compression engines, mechanical-injection engines hold possibilities for the attainment of the ideal conditions for optimum pulverization of the fuel without the complication or disadvantages of air-injection or gas-pressure injection. They also accomplish the elimination of the air-injection apparatus of the Diesel engine which includes (*a*) The air-compressor with its pistons, connecting-rods, cranks, numerous valves and controls, intercoolers, aftercooler and oil separators; (*b*) the high-pressure air-pipes, injection air-receivers, bleeder-valves for discharging moisture and their connections; (*c*) the air type of injection-valve with its high-pressure stuffing-box on the valve spindle and (*d*) the various regulating devices for variable-load conditions.

The benefits secured are simplicity of construction with lower capital and operating costs, continuous reliability with lower operating costs and higher mechanical efficiency, because 10 to 16 per cent of the Diesel engine's power is required to drive the air-compressor. This saving in power results in lower fuel-consumption, particularly at fractional loads. Further advantages are greater ease in operation and maintenance because the operator has to observe only the fuel and lubricating systems and has no high-pressure system to watch; and increased safety in that there are no high-pressure air-bottles to explode. Also, the injection-valves cannot stick open, due to the pressure stuffing-box, and so allow the injection air to discharge the fuel prematurely, which would result in dangerous preignition. When the air-injection valve sticks open for some time, the injection air is soon lost and causes stoppage of the engine. Unless there are reserve air-receivers available, which are charged to full-injection pressure, the engine cannot be run until the receivers are charged. With large Diesel units auxiliary power is provided for pumping up the air-receivers; otherwise the engine would have to be motored for building up the injection-air pressure.

Further benefits are that the mechanical-injection engine has a simpler mechanism for governing under vari-

able loads since, in the Diesel engine, the pressure and quantity of injection air must be varied as well as the quantity of fuel per charge. This is mentioned in the discussion of the disadvantages of the Diesel engine. The time, duration and rate of injection, and therefore the quantity of fuel injected, can be controlled easily in the mechanical-injection system, through simple governing devices. There is also a saving in the amount of space required by the engine.

In the Diesel engine the expansion of the high-pressure injection air in the combustion-chamber produces a refrigerating effect which chills both the combustion air and the fuel. This refrigerating effect necessitates the use of a higher compression to secure a high enough temperature for ignition. Mechanical injection, having no injection air, can utilize a lower ignition-temperature and therefore a lower compression-pressure. The benefits secured are (*a*) lighter and less expensive construction; (*b*) a higher mechanical efficiency; (*c*) easier starting and (*d*) less difficulty in maintaining the compression under long continued service. The mechanical-injection engine gives better speed-regulation for variable loads, particularly in comparison with gas-pressure-injection engines like the Brons and Steinbecker, and it will operate at lower speeds and loads than the Diesel engine. Further, it has a lower fuel-consumption and an increased thermal efficiency. In the past few years of development of the mechanical-injection engine its fuel-consumption has been consistently lowered so that it is now equal to, and in some instances lower than, that of the Diesel engine. Its fuel-consumption is consistently lower than that of the gas-pressure-injection engine.

As compared with other high-compression engines, the disadvantages of the mechanical-injection engine have been due primarily to their inability to attain the ideal conditions for optimum pulverization. These include the objections that

(1) The fuel-injection is initiated as a dribble instead of as a pulverized spray
(2) Pulverization is not carried far enough toward achieving atomization and the fuel is discharged in the form of globules instead of as particles without finite mass
(3) The pulverization is not uniform throughout the period of discharge
(4) The injection ceases with a dribble and after-drip
(5) The globules of fuel resulting from the dribbles and after-drip are deposited on the walls of the combustion-chamber, "cracking" takes place with the formation of carbon deposits and the combustion-chamber must then be cleaned of carbon
(6) Vaporization and gasification are delayed by poor pulverization. In usual designs the fuel injection is begun 18 deg. ahead of compression dead-center. The globules of fuel are subjected to the heat of compression and to the heat resulting from early combustion for a sufficient time, presumably, to produce vaporization
(7) Explosive constant-volume combustion is secured as a result of the early injection of the fuel, instead of the constant-pressure combustion of the Diesel engine. The compression-pressure of the mechanical-injection engine may be considerably lower than that of the Diesel, but its explosion pressure may exceed that of the Diesel; therefore, the mechanical-injection engine must, in many designs, be constructed for higher pressures than the Diesel. This implies a heavier engine
(8) After-burning, or delayed combustion, occurs with poorly pulverized fuel because there is insufficient time for the globules to become vaporized and ignited until late in the power stroke
(9) The intermixture of the gasified fuel and oxygen cannot take place as rapidly and effectively as in the Diesel engine, where the injection air produces considerable turbulence
(10) The complication of the pump that is necessary. With automatic injection valves operated by fuel-pressure difference, the pump must produce instantaneous high pressure and, in conjunction with a governor, control the timing and duration of the injection, as well as meter the small quantity of fuel to be injected
(11) The quantity of fuel injected is so small that the slightest leakage in the fuel system will cause the loss of the high pressure and prevent the operation of the injection-valve
(12) The quantity of fuel between the fuel-pump and the injection-valve must be at a minimum in order that the elasticity of the fuel and of its container cannot influence the manner of injection

Summary

The thermal efficiency of the internal-combustion engine is admittedly superior to that of any other type of prime-mover. A survey of the existing types of internal-combustion engine shows that high-compression engines have the greatest thermal efficiency and are capable of operating on low-gravity oils as well as the more volatile fuels. Developing an engine to meet the small-power high-speed requirements of automotive engines necessitates that the engine be of extreme simplicity to insure ease of operation and continuous reliability. In the Diesel engine the complications of the air-compressor and air-injection system are such as to render highly impracticable the engine's development for that class of service. The great amount of development work expended on the Brons engine since its inception, with the meager success achieved, indicates that the engine has many inherent disadvantages that do not recommend it as being possible of development for automotive service. The thermal-efficiency of the mechanical-injection high-compression engine equals that of the Diesel engine and is superior to that of any other type of prime-mover. In the development of the commercial mechanical-injection engine the path of progress can be traced from the efforts to eliminate the disadvantages of the hot-bulb engine, rather than attempts to substitute mechanical for air injection in the Diesel engine. Naturally, the mechanical-

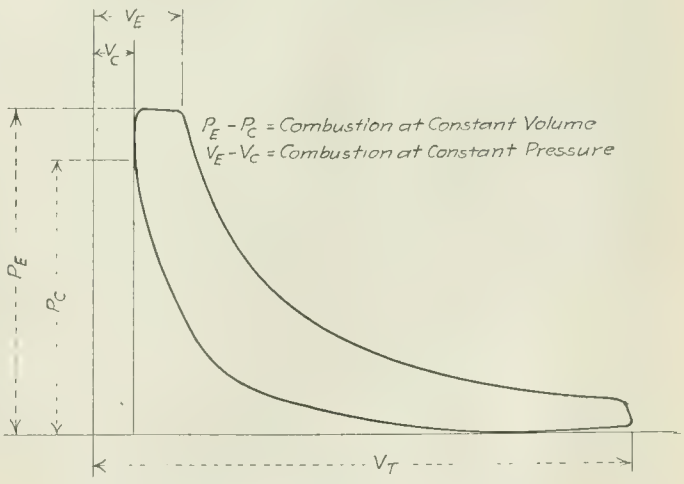

Fig. 12—Typical Pressure-Volume Card Obtained with the Dual Combustion Cycle

injection engine inherits many of the defects of the hot-bulb engine, but marked progress is being made in the elimination of these difficulties.

An analysis of the disadvantages of mechanical-injection engines will show that there are no inherent disadvantages that cannot be eliminated by intensive and intelligent development. The undesirable characteristics retained in the present designs can be attributed to the inability of their constructors to achieve the conditions for optimum pulverization and to a lack of fundamental knowledge concerning the handling of high-pressure fluids.

The final criterion of the economic value of any device for human consumption is its comparative overall cost under continued service, and its ability to meet the particular requirements and desires of its users. In the comparisons given of the various engines, the generalizations made do not indicate the relative value of the advantages and disadvantages for specific classes of work. The problem is complicated further by the kinds of service for which automotive engines are used; they may provide motive power for transportation on land, on sea and in the air and for an infinite variety of isolated powerplants.

The mechanical-injection engine is inherently simpler than the present type of automotive engine; its higher pressures simply require a stronger, more sturdy construction. The success achieved by mechanical-injection two-stroke-cycle engines shows the possibilities of developing two-stroke-cycle engines for automotive purposes with the mechanical-injection system; whereas, the two-stroke-cycle low-compression engine has been unsuccessful except in a very few instances. Estimates of the comparative manufacturing costs of mechanical-injection and present automotive engines have not been attempted, due to the many variables affecting the respective costs. For instance, the quantity to be produced is a very decisive factor in manufacturing costs. That high-compression engines can be sold at a higher price than similar low-compression engines on the basis of their lower fuel costs, is evidenced by the success of Sears Roebuck & Co. in marketing their Brons engines.

The engine-fuel situation is such a new development that builders have but recently realized the scope and importance of the problem. There was no warning until the condition was established; therefore practically no development work has been attempted in this country to produce a satisfactory high-compression engine for automotive use. Until recently, the demand for automotive products was so great that the manufacturers were concerned only with problems of production; they would not contemplate scrapping existing designs. Men with sufficient training to inspire confidence as to their ability to develop high-compression automotive engines have secured their experience with firms producing large stationary and marine engines. These organizations have retained their men so that they have not been available to the automotive industry. Mechanical-injection high-compression engines operating on low-grade fuels can be developed to meet the requirements of automotive purposes, particularly for heavy-duty work such as truck, tractor, railroad, motor-car and motor-boat service and the infinite variety of small isolated powerplants. The data acquired in the development of engines for the services outlined above will render further development for motor-car use a matter of detail progress.

As a motive power for airplanes and airships, the high-compression mechanical-injection engine is believed to be a necessity for the development of commercial aviation. To quote the National Advisory Committee for Aeronautics:

> It is asserted that the capital investment, maintenance charges and fuel costs are all very high in the case of the present aircraft engines and must be lowered materially before the cost of power can be reduced to figures which will make possible the extensive development of commercial and pleasure aviation. The shortage and high cost of aviation gasoline, as well as the complication and relative unreliability of the carburetion and ignition systems, emphatically indicate the necessity for the development of an engine which will operate by direct hydraulic injection of low-grade fuel, with a compression sufficiently high to insure automatic ignition. The committee feels that the early development of an engine of this type is one of the most important technical problems involved in the growth of commercial aviation in this country.

The increased safety resulting from the use of a less volatile fuel than gasoline and the lower fuel-consumption of the mechanical-injection engine are very desirable features. Diminishing the weight of fuel required permits an increase in the pay-load.

It is believed that the preceding comparisons of the various types of internal-combustion engine indicate the advisability of developing a high-compression mechanical-injection engine for adaptation to automotive uses. It was with this conviction that the development work which follows was undertaken.

DEVELOPMENT WORK

The experimental work in the development of a mechanical-injection system for a high-compression engine has been done in the mechanical laboratory of the Carnegie Institute of Technology, Pittsburgh, through the kindness of William E. Mott, director of the division of science and engineering, and C. L. Willibald Trinks, professor of mechanical engineering.

A small surface-ignition engine built by the National Transit Pump & Machine Co., Oil City, Pa., was used, after increasing the compression-pressure to 500 lb. per sq. in. by the substitution of a new piston and a new cylinder-head. The engine, which is illustrated in Fig. 13, is a vertical two-stroke-cycle two-port type, with crankcase precompression. The bore is 5½ in. and the stroke is 6 in., although the effective stroke is 4¾ in. after making allowance for the ports. The compression of 500 lb. per sq. in. was selected for the initial tests, as it can be decreased when desired by simply raising the cylinder-head. The compression necessary for auto-ignition depends upon the ignition temperature of the fuel; the temperature from the compression must be high enough to insure starting with the engine cold. The lowest compression that will permit cold starting is, from present practice, about 350 lb. per sq. in. Fig. 4 gives temperatures resulting from different compression-pressures. The compression ratio necessary for producing a particular compression-pressure can be computed from the equation $P \cdot V^n = \text{a constant}$; where n equals 1.25 to 1.31, depending upon engine conditions.

The determination of the ignition temperatures of fuels by ordinary laboratory equipment is unsatisfactory in that such variables as the manner and quality of injection and the temperatures of the combustion-chamber walls are not considered. Apparatus consisting of a combustion-chamber fitted within a gas furnace and equipped with an injection-valve, and pressure, temperature and

time recording devices, has been used by the British Admiralty Experimental Laboratory[4] for determining the ignition temperatures and the time-lag which elapses from the moment of injection until a pressure rise is indicated in the combustion-chamber.

Mechanical-injection can be accomplished by variable pressure, in which the fuel-injection valve-opening is controlled by fuel-pressure difference; or by constant pressure, in which the fuel-injection valve-opening is controlled mechanically by a cam and lever and the fuel pressure is constant.

The Variable-Pressure Method

The variable-pressure type of injection-valve, an example of which is shown at the left of Fig. 11, consists of a spring-loaded differential plunger that opens when the fuel pressure exceeds the spring resistance. The fuel-pressure variation producing injection is dependent upon the action of the fuel-pump and governor, which action should cause the injection to take place in accordance with the conditions that were stated for optimum pulverization. In addition, the quantity of fuel to be injected must be metered accurately and the time and duration of injection must be under control. The small quantity of fuel to be injected previous to each working stroke is responsible for some of the principal problems in the design of a small high-speed engine. In the experimental engine under discussion the quantity of fuel injected per revolution at full load is about 0.1 cc.

The usual method of metering the fuel is for the governor to hold open the suction-valve or a bypass-valve during the initial portion of the pump stroke and, upon the closing of the valve, the fuel is pumped into the injection-valve. Another method consists of varying the stroke of the pump plunger by a wedge actuated by the governor. With accurate metering by the fuel-pump the problem then consists in discharging exactly the metered quantity of fuel from the injection-valve, and in discharging uniform quantities of fuel for uniform speed and load conditions.

[4]This is described in a paper entitled Fuel Oil in Diesel Engines which was presented by Prof. C. J. Hawkes at a meeting of the North-East Coast Institution of Engineers. An abstract of the paper was published in *Engineering* (London), Dec. 3, 1920, p. 749, and Dec. 10, 1920, p. 786.

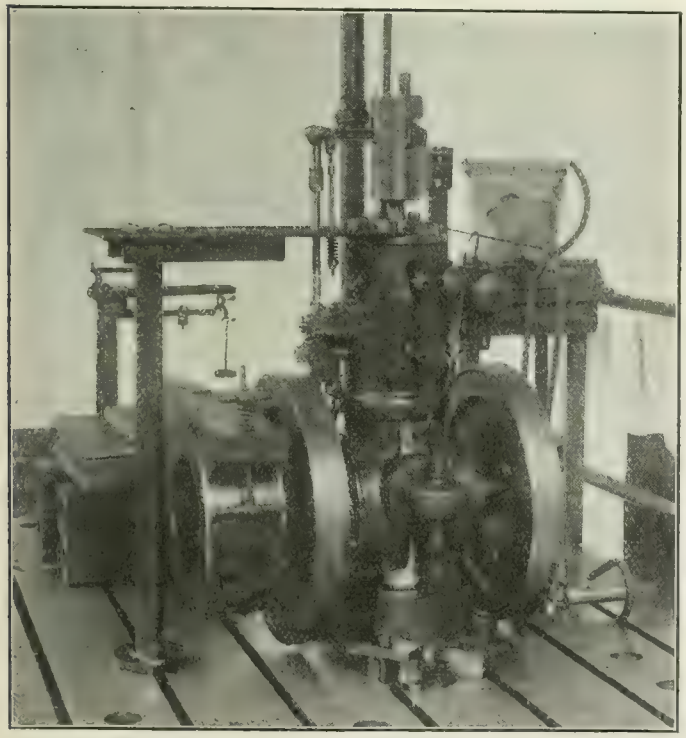

Fig. 13—The Vertical Two-Stroke-Cycle Two-Port Type Engine with Crankcase Precompression upon Which the Experimental Work Described in the Paper Was Done

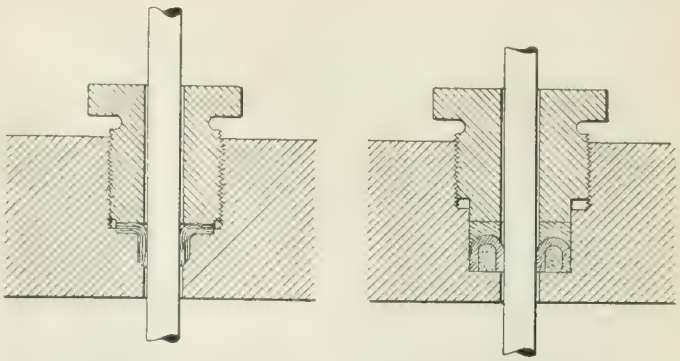

Fig. 14—Two Types of Leather Valve Packing
The Packing at the Left Is of the Flange Type While That at the Right Is What Is Termed a U-Packing.

Conditions which may interfere with or prevent the injection of the metered quantity of fuel, are the (*a*) elasticity of the fuel; (*b*) elasticity of the fuel-containing system; (*c*) elasticity of entrained or entrapped air and (*d*) leakage within the fuel system. The elasticity of the fuel at the pressures used is approximately 2 per cent. This condition makes it necessary that the quantity of fuel in the system, between the pump and the injection-nozzle, be the least possible.

To overcome elasticity in the fuel-containing system it is obvious that the fuel pipes, connections and the like must be made heavy enough to insure absolute rigidity. The poor injection action of many surface-ignition engines can be attributed to this condition. Air gets into the fuel system by being entrained with the fuel, by leakage past the injection-valve during the compression stroke and by leakage during the suction stroke of the fuel-pump. It may be entrapped during the assembly of the fuel system, or it may accumulate while the engine is idle. Air is a very slippery material and will apparently work into the fuel system when the system is so tight that no fuel leakage can occur. Air is so highly elastic that a small bubble in the fuel system will become a minute volume during the working stroke of the fuel-pump but, when the pump starts on its suction stroke, the bubble expands and prevents the pump from drawing in a full fresh charge of fuel. During the following working stroke of the pump, either no fuel will be discharged or the quantity will be less than that desired. This produces an erratic "hit-or-miss" injection action that may cause the injection of an excessive quantity of fuel, thereby producing abnormal pressures in the cylinder. Provision must be made for draining the air from the highest point in the fuel system, preferably in the injection-valve. The fuel system must be arranged so that the air will not accumulate at any other point.

The quantity of fuel in the system, particularly in the injection-valve, should be a minimum to secure as complete and rapid a discharge of the fuel and entrained air as possible. Fuel leakage occurs around the pump-plunger packing-gland and around the packing-gland or similar device of the injection-valve stem. In the injection-valve shown at the left of Fig. 11 the valve-stem is lapped

to its guide and there is slight leakage. High-pressure packing-glands are a source of trouble. A form of plunger packing used satisfactorily in hydraulic machinery at pressures exceeding that encountered in injection engines is shown in Fig. 14 and consists of Vim leather molded into the shapes shown. In the flange packing at the left the nut clamps only the flanged portion; the body of the packing has clearance so that the liquid can surround and force it tight on the plunger. In the U-packing at the right the pressure of the liquid within the U forces the leather against the plunger and the walls of the receptacle, thus sealing the joint. The space within the U can be filled with hemp to prevent collapse of the packing when there is no pressure acting. Leakage may occur at the suction or discharge check-valves, which are usually placed in multiple. Poppet, cylindrical and ball-check valves are shown in Fig. 15.

A form of pipe connection used satisfactorily in Diesel engine practice is shown in Fig. 16. The male part is made of brass or copper, the tubing being brazed into it.

The simplicity of the injection-valve is the advantage of the variable-pressure method; the operation of the valve is entirely automatic, avoiding the complication of valve-gear. The quantity of fuel for each charge can be metered accurately by simple and reliable mechanism incorporated within the fuel-pump, but the disadvantage of the method lies in its inability to discharge the desired quantity of fuel at the correct time and in the manner necessary for achieving complete combustion. The reasons for this inability have been enumerated. Of these (*a*) the elasticity of the fuel and (*b*) the elasticity of the fuel-containing system can be partially obviated by proper design but (*c*) the elasticity of entrained and entrapped air and (*d*) leakage within the fuel system are more difficult to control. Due to the small quantity of fuel to be discharged the presence of any air will interfere with or prevent regular injection of the fuel, and a very slight leakage can easily equal the quantity of fuel it is desired to inject. These adverse conditions make the variable-pressure method practicable only for large slow-speed single-cylinder engines, where the amount of fuel to be injected is a relatively large quantity. The method is in use on all surface-ignition engines and is therefore to be found on many high-compression engines developed by companies building both types. The high-compression engines using this method are usually of the slow-speed single-cylinder type, which can be assembled also as twin-cylinder engines. The conclusion arrived at is that this method is not satisfactory for high-speed multiple-cylinder engines suitable for automotive purposes.

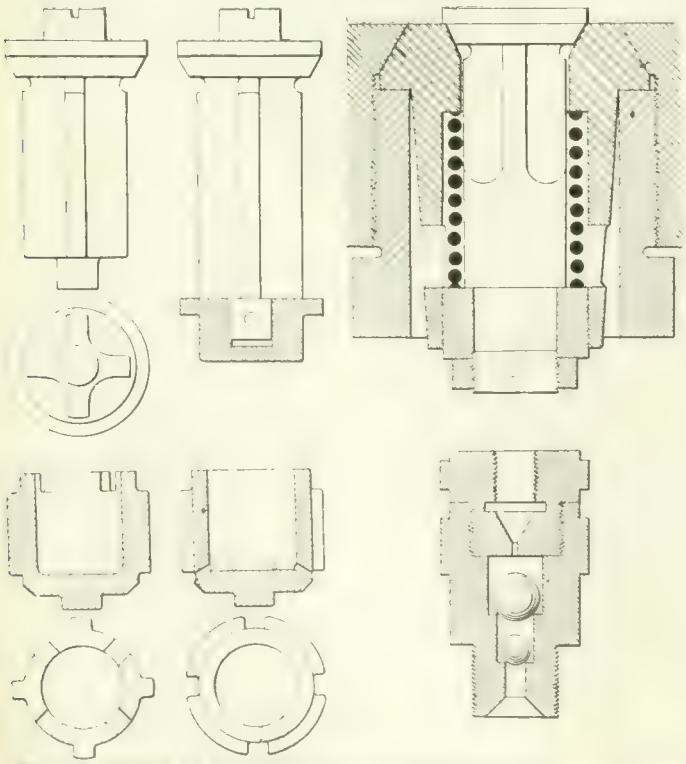

Fig. 15—Types of Poppet, Cylindrical and Ball Check Valves Used in Internal-Combustion Engines

The Constant-Pressure Method

The fuel is supplied to the injection-valves of all the cylinders from a single main supply line which is maintained at constant pressure. The fuel-injection valve shown in the center of Fig. 11 is mechanically operated by a cam and lever; the metering of the quantity of fuel for injection and the time and duration of the injection are under control of the governor acting on the fuel cam and lever. The fuel-pumps are designed to pump two or three times the quantity of fuel necessary for full-load conditions. The fuel-pumps are made preferably from a forged-steel block; the pump cylinders and valve-seats being machined in the block. Packing-glands for the pump-plungers have been shown in Fig. 14 and the check-valves in Fig. 15. Due to the high pressures that the pumps work against, the pump shaft and the eccentrics must have liberal bearing areas and positive-pressure lubrication. The use of several plungers of small cross-sectional area reduces the bearing loads. The pressure of the fuel is maintained constant by a pressure regulator holding suction or bypass-valves open during a portion of the pump stroke, or by a spring-loaded relief-valve similar to the pressure-regulating valve shown at the right of Fig. 11. The flat seat of the pressure-regulating valve gives less trouble from chattering and wear than a mitered seat. The seat parts are made of hardened steel.

The constant-pressure injection-valve shown in the center of Fig. 11 consists of a differential plunger, spring-loaded by a valve-spring and also by a lift spring which forces a valve spindle onto the differential plunger. A cam-operated lever lifts the valve spindle, relieving the lift spring and permitting the fuel pressure to lift the differential plunger against the valve-spring. The movement of the differential plunger removes the injection-valve from its seat and permits the fuel to be injected into the combustion-chamber. The fuel cam action controls (*a*) time of injection; (*b*) lift of the injection-valve; (*c*) duration of injection; (*d*) quantity of fuel injected and (*e*) manner of injection. Variations in the time of injection can be accomplished by angular advancement or retardation of the fuel cam. The lift of the injection-valve and the duration of the injection are determining factors in the quantity of fuel that will be injected. The injection-valve lift, determined by the fuel-cam lift, must be sufficient to permit free injection of the fuel without dribbling. The duration of injection depends upon the angular period of the fuel-cam. As the fuel pressure is constant, the injection-valve lift should remain practically constant during the period of injection. Varying the quantity of fuel for different load conditions should be accomplished by varying the duration of the injection period; in other words, varying the cut-off ratio, or the length of the constant-pressure line. The rapidity with which the injection-valve opens

and closes is a determining factor in attaining the conditions of maximum pulverization. With the injection-valve filled with fuel maintained at constant pressure and the fuel cam acting directly on the injection-valve, the injection action can be much more rapid than with the variable fuel-pressure generated by a cam and pump removed from the injection-valve.

The constant-pressure method is not subject to the adverse conditions which interfere with injection in the variable-pressure method. The constant fuel-pressure obviates trouble from the elasticity of the fuel and its containing system and also does not permit the entrapped air to expand and cause erratic injection. Any leakage that occurs in the fuel system with the variable-pressure method is a wastage from the metered quantity of fuel that it is desired to inject. In the constant-pressure method the metering is done within the injection-valve so that leakage in the system does not affect the quantity to be injected.

In view of the considerations stated, the constant-pressure method is preferable for small high-speed engines in that the exact metered quantity of fuel is positively injected at the desired time, and in that uniform quantities are injected for uniform speed and load conditions. The experimental work has shown consistent progress but has not advanced to a point where further disclosure of methods and results is advisable at this time.

The imperative necessity for the conservation of the world's petroleum resources is too well realized to require repetition. It behooves the automotive industry to have an open mind in considering new types of engine for development into more economical engines for the future. It is hoped that the paper submitted has been instrumental in securing recognition of the mechanical-injection high-compression oil engine as the logical selection, of the known types of internal-combustion engine, for development to meet the requirement of automotive equipment. The development problem is a big one, but it is certainly not one that the automotive industry, which has been the very embodiment of the spirit of progress, need fear to attack. America leads the world in the production of automotive equipment, but to lead in the development of more economical types will require the cooperation of the entire automotive industry, including its business men and its engineers.

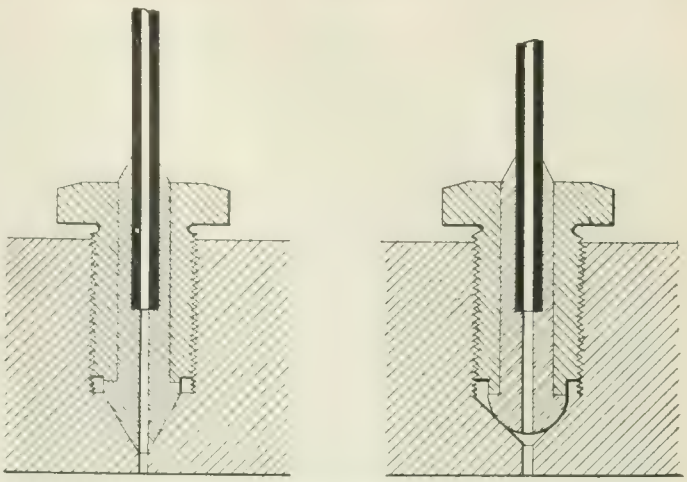

FIG. 16—A FORM OF PIPE CONNECTION USED WITH GREAT SATISFACTION IN DIESEL ENGINE PRACTICE

The encouragement and assistance rendered by the administrative and instructional staff of the Carnegie Institute of Technology is gratefully acknowledged. Acknowledgment is due also to Stanley L. Connell for his collaboration in the development work and the preparation of this paper.

THE STRAIGHT-EIGHT ENGINE

SO much has been suggested and reasoned concerning the fundamental principles which led to the recrudescence of the eight-cylinder-in-line engine for racing purposes that it is most interesting to learn the views of those engineers in France who sponsored the movement. The straight-eight appears to have been adopted because it is well balanced; allows of a higher number of revolutions than is possible with four cylinders of equal displacement; because the lighter reciprocating parts, such as valves, though multiplied in number, are less highly stressed, and hence should prove more reliable; and because with this design cooling, in the sense of the avoidance of distortion, is more thoroughly effected. It would seem, therefore, that some of the engineers on this side of the Channel were correct in their assumptions. Others, however, are very definite in their preference for the large cylinder on the score of the possibility of lighter construction. There seems to be the making of an illuminating controversy as to whether the car of the future should have a small high-speed high-efficiency engine with many cylinders, or the larger slow-speed engine of the four-cylinder variety. If the opinion of car users as a whole were taken, and the effect of the Treasury tax on bore were for the moment put aside, we think that opinion would be more or less evenly divided. One side would favor the large soft engine, characteristic of so many American cars, with its top-speed capabilities, while the other would embrace the high-speed engine and the four-speed gearbox, which is common to British medium-power car design.—*Autocar* (London).

BRITISH AND AMERICAN INCOME TAX

THE British Royal Commission on Income Tax estimates that there were 3,406,000 taxable incomes in Great Britain in 1918, producing income and supertax amounting to £272,816,000. These figures compare with 1918 Internal Revenue returns of 4,425,114 taxable incomes in United States, yielding a tax amounting to $1,127,721,835.

COOPERATION AND COORDINATION

COOPERATION means essentially the working together of equals, with none surrendering the right to independent action should self-interest demand it. Coordination means the surrendering of certain individual prerogatives and the submission to the authority of a superior for the common good.—*Electrical World.*

Research in Industry

By L. A. Hawkins[1]

Semi-Annual Meeting Paper

THERE are three steps common to all researches; the statement of a question, the performance of one or more experiments to obtain relevant data, and the formulation of conclusions from those data to answer the question wholly or in part. And yet the term research covers multifarious activities different widely in purpose, methods and importance. Compare Millikan's classic experiment with oil drops for measuring by an entirely new method the charge on an electron, an experiment requiring imagination, a high degree of resourcefulness and delicacy of manipulation, with results of enormous interest to science but of no immediate commercial utility, with such an investigation, for instance, as one now being conducted at the University of Illinois on fatigue effects in 3-per cent nickel steel, an investigation for which the chief requirement is an adequate testing equipment, and the results of which will be of immediate practical utility to the designers of steam turbines. A definition of research that covers both of these investigations must obviously be general in its terms.

Research of a type most useful to one industry may be largely inapplicable to another. This paper will confine itself to research in electrical manufacture and will leave it to you automotive engineers to judge how far our experience is applicable to the automobile industry.

The General Electric Co. was among the pioneers in this country in the field of industrial research. The laboratory at Schenectady, starting from small beginnings about 18 years ago, has grown until we now have about 300 people on our payroll, about one-quarter of whom are trained pysicists, chemists, metallurgists and engineers. In the limited time at my disposal it would be futile to attempt to describe all the different kinds of work in progress in the laboratory. There would be time to hardly more than mention them, and the result would be about as interesting as a catalog. So I shall try to present the picture rather impressionistically, referring to specific lines of work only by way of illustration.

Classes of Research

Our work in the laboratory naturally divides itself into two general classes, distinguished from each other by the immediate objects in view, by the methods by which those objects are sought, and also, to some extent, by the type of mind best adapted to pursue those objects. In the first place, we have researches which have a concrete object in view, a definite commercial goal in sight. On the other hand, we have researches more in the nature of pure science, the object of which is to extend our knowledge of things electrical, with no concrete object in sight. I can illustrate those two classes of work by two of the best known achievements of the laboratory, both in the incandescent-lamp field; one the production of drawn tungsten, the other, the gas-filled lamp. Both of these, as you know, were of great importance, and yet the kind of work which led up to them was totally different in the two cases.

When tungsten lamps were made from the fragile, costly, squirted filament it was obvious to almost anyone that the real way to make a tungsten lamp was to get tungsten in the wire form and draw it; the difficulty was to find out how to do it. A great many metallurgists tried and failed, but Dr. Coolidge succeeded. Now he succeeded by persistent, resourceful experiment, trying this, that and the other thing; when it failed, repeating, changing one thing or another; making a little progress here, learning a little something from a failure there, but always moving forward toward the goal which was more or less clearly visualized from the start, until finally he had the thing he was after, drawn tungsten.

The origin of the gas-filled lamp was totally different. Dr. Langmuir had been conducting what you might call an academic investigation of the evaporation of hot tungsten, and he found an interesting scientific fact, that the rate of the evaporation of tungsten is affected to a remarkable extent by gas pressure. While he was on that investigation he was requested by the heating-device department to determine the laws governing the loss of heat from small wires in air. Much had been published on that, but Dr. Langmuir found that the accepted laws were wrong; he discovered what they really are, and having determined that, and having found this effect of gas pressure on the rate of evaporation of tungsten, he put the two together and saw that it would be possible, with a large enough filament, concentrated by winding it in a helix, to produce a lamp considerably more efficient than any vacuum lamp. Before the first experimental lamp was life-tested, he had figured out on paper just about what life could be expected at a given efficiency from given sizes of lamp, both with nitrogen, and with argon of which there was not a bit available for use in this country at the time; and all the tens and hundreds of thousands of tests made since that day on different types of gas-filled lamps have in one way done little more than to establish over and over again the correctness of those calculations Dr. Langmuir had on paper before the first experimental lamp was life-tested.

Those two developments illustrate, I think, very well the distinction I wish to make, and I shall keep that distinction more or less before you in describing the work of our laboratory. Take the first kind of work, that is, the work which has a concrete object, a definite commercial goal, before it. Now that may be subdivided into two classes; that is, some of that work has to do with improving the existing products of the General Electric Co. Many lines of investigation of that kind are started by problems brought into the laboratory by engineers or by factory men. Some of these problems may require only a few days or a few weeks to solve. For instance, recently the switchboard department wished to find a material it could use in the bellows type of relay which was not only absolutely air-tight but would retain complete flexibility at very low temperatures. The material was found, animal bladder, and it was only a very short job to work out the technique for tanning it to render it fit for service. That is an illustration of the kind of problem which ordinarily can be solved in a few weeks.

On the other hand, some of those problems may require years of investigation. For instance, our engineers

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wished to find an insulating varnish capable of operating for a long time at relatively high temperatures without getting brittle. That meant an investigation of linseed-oil varnishes extending over a period of years, a study of the phenomena of the polymerization and the oxidation of varnishes, with the net result of producing some varnishes having the desired characteristics, materially improving the quality of the coils on which these varnishes are used, and incidentally, in many cases, reducing the factory cost. Some of these problems that are brought in, in that way, require a certain amount of productive work in the laboratory. For instance, some years ago, the railway department wanted a high-melting solder having certain characteristics, for brazing armature leads to commutator bars. We found an alloy of silver and cadmium that filled the bill, and ever since then we have been manufacturing in the laboratory that alloy in small quantities and supplying it to the railway department. Sometime the manufacture may be on a larger scale, arc-furnace work, for instance, where a non-magnetic alloy with high tensile-strength is required for high-frequency alternators.

Sometimes the problem is not one of new materials but of a new process, as, for instance, applying the copper brazing method developed in the laboratory to join certain points which before had been joined with rather expensive mechanical work and without an entirely satisfactory job. Still other investigations may be brought to us in the way of complaints from the outside. In some cases only an investigation may be required as to why, for instance, some particular turbine, in some particular locality, corrodes more rapidly than it should. On the other hand, it may mean that a considerable amount of work will be involved; as, for instance, the development of a new grade of carbon brush to take care of a particularly difficult motor service somewhere; but all of those kinds of work, brought to us in these different ways, some of them, of course, initiated by the laboratory, have to do, as I said in the beginning, with improving the existing apparatus of the company.

Researches with a Definite Goal

But there are other kinds of work, other investigations, which, like those I have just mentioned, have a perfectly definite object in view, but at the same time have as their purpose producing some new device and extending the scope of the work of the General Electric Co. Now, of course, the development of those new devices must in most cases be preceded either by some new observation or by a better understanding of some physical or chemical phenomenon. For instance, some years ago, while one of the gas-filled lamps was burning on life-test, it burned out near the lead, but it continued to burn, holding a short arc between the filament and the rather heavy lead. Enough current was passing through that arc and the rest of the filament in series to maintain the filament incandescent. It was a curiosity for several days, but we investigated the characteristics of that arc, an arc in gas between a hot filament and a relatively cold electrode; we found that such an arc has rectifying qualities; and the result was the development of the "tungar" rectifier, which is being made and sold in large quantities today for charging small storage-batteries. That was a new device resulting from a casual observation.

After Dr. Langmuir had discovered the laws governing pure electron-discharge in a high vacuum, Dr. Coolidge saw the possibility of building on those laws a new type of X-ray tube which would be much more reliable and constant in its characteristics, and much more convenient and easy to control, than the existing X-ray tube, and "the Coolidge tube," as it is known, was the result. Many of you may know more or less what that has done for X-ray practice. It not only gave the roentgenologist a much better tool to do the work he was already doing, but it has made possible many applications of X-rays which would not have been possible with the old type of tube, such as taking the X-ray to the bedside of a patient, or taking plates of the chest in from 0.025 to 0.100 sec., thus making stereoscopic work on the chest possible. We believe that the uses of X-rays are only just beginning, and it is the Coolidge tube which is opening up all these possibilities. So much for the kind of work that has a definite object in view.

We have at all times much of the other kind of work in progress in the laboratory. For instance, we have now one group of men who are passing homogeneous X-rays through little flasks of powder and photographing the result. They get spectra in that way, and from those spectra it is possible to calculate the relative positions and the relative spacings of the atoms which make up that particular material. In other words, it is one method of investigating the structure of matter, that is, the relation of the atoms to each other and their spacing. Another group is going farther than that, studying the structure of the atom itself, partly through studying the mechanism of the ionization of gases; and two or three other leads are being followed converging on the same point.

Those are only two instances out of a number of investigations of that kind which are being, or have been recently, conducted. Now it might well be asked by one unfamiliar with research, "What is the use of an industrial research laboratory doing that sort of work?" Part of the answer has already been given; that is, two things have been mentioned, the gas-filled lamp and the Coolidge X-ray tube, which owe their origin to exactly that sort of investigation. It has been our experience so far without exception that every important discovery which we have made regarding the fundamental laws or phenomena of physics or chemistry has resulted sooner or later in something of considerable practical utility and of commercial value to the General Electric Co.

As a matter of fact, I think it could be shown not only in the electrical art but in other arts besides, that many of the big steps forward, the radical things, have come from men who were not engaged directly in trying to improve that art. Take, for instance, the art of communication, the transmission of speech. The first telephone engineer was the man who made the first speaking-tube. He may have been a plumber or a tinsmith, and the plumber or tinsmith was the only telephone engineer for many years, but it was not a plumber or a tinsmith who produced the microphone and created real telephony. On the other hand, when the next big step was made, it was not the men who were working on telephony or upon telegraphy who discovered radio. Maxwell, Hertz and Lodge were physicists working to extend the limits of knowledge. It was they who discovered the waves which we now use in radio telegraphy. Now that radio telephony is beginning to overtake radio telegraphy, again we have a case in point; Dr. Langmuir, in the laboratory at Schenectady, was not thinking of radio, but was working on the "Edison effect" in incandescent lamps, when he made the fundamental discoveries on which he was able to base the design of a high-power vacuum-tube adapted to transmit radio, and in that way made possible.

for the first time, the transmission of speech by radio over long distances.

The academic study of the "Edison effect" gave us both the high-power transmitting tube for radio now known as the pilotron, and also the Coolidge tube; and we feel that that development is really only started. The tube which we had a year or two ago was good for a few hundred watts; now it is a few kilowatts, and we do not know where it is going to stop. I believe it would not be rash to prophesy that sooner or later high-power vacuum-tubes will make their influence felt in the real power field.

Justification of Industrial Research

For the reason, among others, that almost invariably from each new discovery or each new advance in science, pushing forward the boundary line between the known and the unknown, we do uncover something of commercial utility, we believe that an organization like our research laboratory is justified in continuing that kind of work. But there is another value to the laboratory, and through the laboratory to the General Electric Co., in that kind of work. We could not hold, in the laboratory, some of our best men unless we had that kind of work in progress. There is one type of mind that likes to see its ideas taking tangible form, likes to be working on something specific, so that it can chase that idea right through to something that it knows is of general utility; the man does his best work with a definite goal before him. There is another type of mind that is interested in the theoretical, in the abstract, rather than in the concrete, that does its best work and finds its greatest enjoyment in reaching after the unknown. Men of both types are necessary to our work. It is the men interested in the concrete, with a genius for embodying ideas in new and useful materials and devices, who for the most part produce the practical results that furnish the immediate financial justification for the maintenance of an industrial research laboratory; it is the men interested in theory, with a genius for discovering new and fundamental facts, who for the most part open up the broad new fields for exploitation.

So-called pure science and applied science are not antagonistic. Both are benefited by close association. Each is a stimulus for the other. Close contact with practical problems suggests continually new trains of thought to the scientific worker and helps him to keep his perspective. Close contact with research in pure science assists the worker on practical problems, by continually suggesting new methods of attack and new fields for development. In the industrial laboratory there is no sharp line between pure and applied science. One often merges into the other so gradually that no one could say where the line was crossed. A man who initially was engaged on an academic investigation may later find himself concentrating on the practical application of some phenomenon discovered in his original experiments.

It is because the industrial laboratory has brought together in mutual helpfulness pure science, applied science and engineering development, and has supplied them with adequate equipment backed by all the facilities of a large manufacturing plant, that it has achieved its marked success. It has proved itself a financial asset to industry and has contributed largely to the advancement of science. And great as the profits to industry have already been from the products of its laboratories, it is a safe prophecy that in the end industry will profit most by those results which today must be classified as contributions to pure science; for just as all of our engineering today is founded on the scentific discoveries of the past, so the engineering of the future will be based on the new knowledge science is now unfolding, and in that discovery a large and increasingly important part is being played by the industrial laboratory.

TWO-MAN ALTITUDE FLIGHT

WHAT is believed to be a new world's altitude record for pilot and passenger was made on May 6, by Lieut. J. A. Macready with Roy S. Langham as observer, when he reached a corrected indicated altitude of 34,150 ft. above sea level in a Lepere biplane equipped with a Moss supercharger. This airplane is the same one in which Major Schroeder made his world's altitude record for pilot alone and for pilot and passenger.

No difficulty was experienced by the pilot except the discomfort caused by the extreme cold at the great altitude and by the frosting of his goggles. Upon removing his glove to attempt to wipe ice from his goggles, his left hand became so stiff from cold that he lost the use of it until the warm air at a lesser altitude restored the circulation. The engine and supercharger functioned very satisfactorily.

While the figure given does not represent the true altitude above sea-level actually attained by the airplane, it is the figure upon which altitude records are granted. The corrected indicated altitude is dependent solely upon the pressure of the atmosphere in which the airplane is flying. If two airplanes attain the same corrected altitude on different days, which of the two airplanes reaches a higher true altitude depends on the temperature existing in the atmosphere between the airplane and the ground which is, of course, a matter of luck. It is for the purpose of eliminating the element of luck that the International Aeronautic Federation disregards true altitude in determining records, since it is obvious that, if one airplane reaches a higher corrected indicated altitude than another, which means lower air-pressure, it could out-climb the first airplane provided both were flown under identical atmospheric conditions. To obtain the correct indicated altitude, all the temperature and pressure corrections of the barograph used must be accurately known and carefully applied to the observed readings obtained on the flight.

Major Schroeder's corrected indicated altitude for the one-man record was 38,180 ft. by the Bureau of Standards computation, and for the two-men record 33,350 ft. computed by the Flight Test Branch of the Air Service at McCook Field. —Air Service News Letter.

The Requirements of Aeronautic Powerplant Development

By G. J. Mead[1] and L. E. Pierce[2]

Semi-Annual Meeting Paper *Illustrated with* Chart

THE object of this paper is to discuss the probable trend of aeronautical powerplant development, showing the reasons for the types which are likely to become more or less standard. Such a discussion involves a brief survey of the present situation, a review of the development of the various engine types, an analysis of the effect of their characteristics on airplane performance and a consideration of the proper installation of powerplants in the airplane.

The end of the war left us with very highly developed military powerplants, capable of enabling man to outdo the performance of birds in flight. This accomplishment was principally due to the necessities of the war. As a result of war requirements, designers strove increasingly to make lighter and more powerful engines. The limit of the power available from a single cylinder caused more and more cylinders to be added until, at the close of the war, engines were being developed with as many as 24. Various arrangements of cylinders existed. Practically all aimed at shortening the powerplants as much as possible. When more power was required and could not be secured by a given number of cylinders in a single bank, double, triple and even quadruple banks of cylinders were used, with a maximum of eight cylinders in a bank. Besides fixed-cylinder water-cooled engines, rotary air-cooled engines and radial air and water-cooled engines were used. Most of the engines were of what might be termed the racing type, being high-strung, light and delicate. The power range at the close of the war was from 60 to 1000 hp. Practically no commercial engines were developed. The war experience might well be likened to a tremendous experiment made under pressure, which came to a sudden stop with the ending of hostilities without answering the question of what were the best type of engine for each service. Therefore, a maze of engine types and powers are left, which are more or less fitted for particular military purposes but are, for the most part, unsuited for any other service.

The problem which now confronts the industry is one of establishing standard types for the powerplants required by each service, and setting up reasonable power requirements for each unit. With so many varieties of engines, it is obvivous that the art cannot be put upon a commercial basis, nor is the condition satisfactory for military purposes. In considering the situation from this point of view, it is necessary first to know what the services now are to which an engine can be put. There has been a small but increasing demand since the close of the war for what might be termed commercial engines which, due to the requirements of this particular work, have entirely different characteristics than the military powerplants previously available. It is still true that the principal demand is for military engines, and it is necessary for the safety of our country to develop this type unceasingly. There is great need for the development of satisfactory commercial powerplants. This is not because of the demand, but to stimulate it. With these engines available, the success of the first undertakings in commercial aviation will be assured. A third service, which might be termed sport, will be developed ultimately. This service will require engines as different from the others as our passenger-car engines are from those used for racing or trucks.

For each service, factors must be developed to permit the making of correct comparisons of the performance of the different engines. The engineering method of doing this consists in comparing certain constants for each design, which have been developed by experience. These constants necessarily apply only to a particular set of requirements or, in other words, to one particular service. It so happens that we are accustomed now to judge the performances of all aeronautical engines by constants which are in reality only applicable to military engines. For this reason, aeronautical engineers unconsciously consider that an engine must weigh less than 2 lb. per hp., and that the fuel consumption is satisfactory if it is in the neighborhood of 0.50 lb. per hp-hr. Such an engine rarely lasts more than 50 hr. without a top overhaul, which is comparable with 6000 miles of air-travel. The airplane designer is inclined to believe he must have maximum power and minimum weight at any cost. In this case, the cost is the reduced life of the engine. The commercial requirements involve the use of entirely new factors, since the prime requisites of commercial work are efficiency and durability, which changes the engine design considerably. Our definition of durability is long life. All aeronautical engines must be reliable, but in the past durability has been sacrificed for light weight per horsepower. The weight factor for engines with these requirements becomes at least 3½ lb. per hp. Commercial engines should run at least 16,000 miles without a top overhaul, with a fuel consumption approaching 0.40 lb. per hp-hr. These constants contrast sharply with those for the military requirements. In this connection it is interesting to compare these figures with those for the Wrights' first engine, which weighed approximately 7.6 lb. per hp. This is a decided indication of the progress that has been made.

Consideration is given next to the different types of engine, and then a study is made of the particular types most suited for each service. Before taking this up, it is perhaps advisable to point out that fuel consumption is not related to the type of engine. By using high compression and sacrificing some power, which means increasing the weight constant, approximately equal fuel

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economies can be obtained from any of the various types of engine. It follows that military engines naturally sacrifice economy to keep the weight factor low. The form or type of an engine is due principally to the power limitations of an individual cylinder, as previously pointed out. From the standpoint of the airplane designer it is desirable to keep the engine as compact as possible, principally limiting those dimensions which increase head-resistance and tend toward bulky powerplants. This encourages the use of engines having a single vertical bank of cylinders. When more power is required than can be obtained with this arrangement, it is necessary to go to multiple-bank types. It is obvious, therefore, that it is necessary to take up next the question of what limits the power of an individual cylinder.

The power available from a single cylinder depends upon the dimensions of the cylinder, the speed of operation and the compression ratio. Other items, such as the fuels used, the timing and the size of the valves, will not be considered in this connection, since we are able so far to provide for these requirements regardless of the size of the cylinders and they therefore do not impose any limits on cylinder performance. Taking up the cylinder dimensions first, we find that a 5½-in. bore cylinder was practically the limit at the close of the war, which made available some 45 hp. per cylinder and resulted in a large number of cylinders where considerable power was required. The limiting factor for the bore appears to be the reciprocating parts. With large bores, the pistons become difficult to cool in the usual manner. This is not an insurmountable restriction, since several expedients are known for cooling pistons in other ways. The principal reason is that the power required to overcome the inertia of the reciprocating parts increases rapidly with the increase in the cylinder bore at a given speed and, since this power must be subtracted from the available indicated horsepower of a given cylinder, the brake horsepower is reduced. Indicated mean effective pressure is independent of cylinder size, at least so far as our experience to date goes. Therefore, as the cylinder bore increases, the reciprocating weights increase and the speed of the crankshaft must be decreased to permit the obtaining of good brake mean effective pressure. At present, cylinders of 7-in. bore are being operated successfully at speeds as high as 1400 r.p.m., with brake mean effective pressures corresponding to those obtained with any of the smaller cylinders. Powers as high as 65 hp. are now obtainable from a single cylinder of this size. This is approximately a 30-per cent increase in power over previous practice, and permits important changes in the types of engine for the different powers required. Carrying bore sizes to an extreme, a point will be reached where no increase in power will be obtained by further increases, due to the very low crankshaft speed which the reciprocating parts of this particular size will permit. What this point is, has yet to be proved.

Taking up the question of stroke, we find that the principal restriction upon increasing it beyond a certain dimension similar to the bore, is the rapidity with which the weight per horsepower of the engine increases. It has been found that a "square" engine, one having the bore equal to the stroke, makes the lightest possible construction. When the valves are placed in the head, it is very difficult with long strokes to secure sufficient valve-area, and still cool them properly so that they will stand up under the temperatures resulting from the high mean effective pressures. Of course, increasing the stroke increases the piston speed at any given number of revolutions per minute of the crankshaft, but so far no difficulties have been experienced from this cause. It appears, therefore, that some increase in power can be had by lengthening the stroke on commercial engines, but not for military engines owing to the weight limitations.

The speed of the engine, or its rate of doing work, is an important factor. Of course, in obtaining maximum power with a minimum weight it is necessary to run the engine just as fast as possible. The limiting feature here becomes the propeller speed. With the pursuit ships it is possible to run the propeller up to 2100 r.p.m., but for commercial work, due to lower flying speeds, it is not desirable to turn the propeller nearly so fast, because of the effect on propeller efficiency. A propeller speed of 1800 to 2000 r.p.m. is considered more or less standard for military work, and from 1000 to 1400 r.p.m. for commercial work. In the case of a dirigible, the propellers turn about 550 r.p.m. The question immediately arises, Why not gear the engine? For military work, no commercially manufacturable gearing has been devised which permits a reasonable powerplant weight per horsepower. It seems perfectly possible to use gearing for very large commercial airplanes and dirigibles, where the size and weight of the gear-reduction is not of such importance. It has been found desirable to increase the compression-ratios as much as possible, to permit the maximum power output of the engines at great altitudes. The maximum compression-ratio from which a gain in power can be secured is 7 to 1. So far, the size of the cylinder does not seem to limit the use of such a compression. Above 5¼ to 1 it is desirable to use some anti-knock substance such as benzol, if it is necessary to operate the engine on the ground under full power.

From the foregoing, it will be seen that we have not reached, as yet, the maximum power available from a single cylinder. It is true that, as the bore increases, the speed must be decreased somewhat. It is desirable to keep the ratio of bore and stroke as nearly unity as is possible, especially for military engines. The maximum compression-ratio is fixed at 7 to 1. Without dope, it is possible to secure 130 lb. per sq. in. mean effective pressure in water-cooled cylinders, and with dope as high as 145 lb. per sq. in. it follows that we shall be able to produce much larger powerplants with fewer cylinders than formerly, if a demand for them arises.

Future Types of Engine

In taking up the consideration of future types, based on the above conclusions, it is desirable to dwell for a moment upon a few of the general conditions and requirements facing the aeronautical engineer today. All types of engine must operate under wide variations of temperature and pressure, the ranges of temperature being from 50 deg. below to 100 deg. above zero fahr. and of pressures from the usual sea level of 30 in. of mercury to as low as 8 in. Besides these atmospheric conditions, aeronautical work requires that the engines be the lightest of all prime-movers, which involves the use of the strongest and lightest materials known. Reliability is an absolute necessity since, in heavier-than-air machines, the failure of the powerplant deprives the pilot of the ability to navigate his ship at will. This does not mean necessarily that any serious accident need result, but it prevents accurate maneuvering.

Due to the variations in the air temperature, it becomes more difficult to provide means for keeping the engines at the proper operating temperatures. Both air

and water-cooling have been used, but no standard has been determined upon, except that water-cooling seems to be the more generally favored. Great strides are being made in the development of air-cooled cylinders for aviation work. The British report being able to obtain as high mean effective pressures as with water-cooled cylinders. So far, the maximum mean effective pressure which has been developed in this country with large air-cooled cylinders is in the neighborhood of 110 lb. per sq. in. With relatively small cylinders, pressures as high as 125 lb. per sq. in. have been secured. Thus far satisfactory air-cooling has been limited to radial engines. Air-cooling has advantages for an airplane, due to the tremendous differences in temperature under which the engines are forced to operate. It also makes the engine somewhat less vulnerable when used for military purposes. This does not seem to be a very important feature, since most planes that are shot down apparently fall because of fire rather than any other cause. The disadvantages of this type of cooling are that it allows, so far, relatively low mean effective pressures, increases the parasite resistance of the airplane considerably, and does not permit easy temperature-control. Another point that must be borne in mind is the effect of the accessory weights upon the ultimate powerplant weight. For example, let us assume that the maximum power that one carbureter can take care of is 200 hp. If 300 hp. is required, two carbureters will be necessary, but without additional carbureter weight it may be possible for them to supply satisfactorily a 400-hp. engine. It will always be found, therefore, when it is necessary to double up on accessories such as magnetos and carbureters, that unless the power is also proportionally increased the weight of the resulting engine will be in excess of that in which the accessories are used to their maximum capacity. With the general restrictions in mind, we are able to proceed with a detailed consideration of the different types of engines in connection with the cylinder arrangements.

The "in-line" type of engine is most particularly adapted to aviation work, due to its low head-resistance and the simplicity of its parts. For this reason it makes an ideal commercial type of engine. Its weight, however, is greater per horsepower than that of the V-type engine. Four cylinders in line are not satisfactory, due to both the power limitations and the vibration. Six cylinders form an ideal combination, since it is possible to obtain powers as high as 400 hp. from this number, and the engines are perfectly balanced mechanically. The weight factor for a six-cylinder engine is from 2.5 to 3.5 lb. per hp., depending upon the service. The limit of the number of cylinders that can be put satisfactorily in one line is eight, due to the torsional vibrations of the crankshaft. The weight of such an engine is about 20 per cent greater per horsepower than for a six-cylinder engine, due to the long crankshaft and crankcase, but for such uses as dirigible work the durability and efficiency of this type are sure to recommend it. Over 500 hp. is available in a single unit of this type. Six-cylinder engines are much used, but "in-line-eights" have not as yet come into service.

Under V-type engines are classed the lightest powerplants; therefore, it is a type much used for military service. The smallest number of cylinders in a single bank that has been used successfully is four. In this case, the two banks are 90 deg. apart. The V-type eight-cylinder engine is undoubtedly the lightest water-cooled engine known, for the reason that it has the shortest crankshaft for a given power. Weight factors of 1.45 lb. per hp. have been secured from this type of engine. For pursuit work this is the most important consideration. It makes the use of these engines for this work practically a necessity, especially when consideration is given to the effect of weight upon the performance of an airplane, which point will be taken up later. The one drawback to the V-type eight-cylinder construction is the tendency for the engine to vibrate in a horizontal plane. This is noticeable only with heavy reciprocating parts and at slow engine speeds. It has already been proved that eight cylinders of sufficient power to give 400 hp. at 2000 r.p.m., which is a pursuit propeller-speed, do not involve reciprocating parts of sufficient weight to make the vibration serious to the plane structure. It is necessary, of course, to exercise care in the design of mountings for these engines to take care of the horizontal vibration. Pursuit work is a matter of performance, just as with a racing automobile. In neither service is exceptional smoothness required if it in any way deducts from the performance. V-type 12-cylinder engines are used considerably for short-distance bombing airplanes, where the engine weight is a factor. Small engines of this type will undoubtedly be in demand for pleasure purposes, just as they are in automobile work. The best weight-factor from a 12-cylinder engine is in the neighborhood of 1.9 lb. per hp. With a given displacement the 12-cylinder engine presents much more exposed cylinder and port area to the cooling water and therefore a considerably larger radiator is required than for a fewer number of cylinders. This increases the total weight of the powerplant and also its head-resistance.

Radial Engines

Serious consideration has been given to radial engines, particularly by the British. It was originally thought that this type of engine would be lighter per horsepower than any other and that, with its concentrated mass it would be particularly adaptable to pursuit work; and in addition that, the customary cooling system being eliminated by using air-cooled cylinders, the plane could not be brought down due to any damage to the cooling system. It has been found that the weight-factor for this type of engine is about 2 lb. per hp., when the design is such as to permit the engine to operate satisfactorily for 50 hr. This is practically the same weight-factor as for the V-type eight-cylinder water-cooled engine complete with water and radiator, so that there is really no saving in weight. Moreover, a radial engine of a similar power to that of the V-type eight-cylinder engine has an enormously increased parasite resistance. Radial engines properly balanced are very smooth-running and compact as regards the concentration of weight. The temperature control is very difficult. Fuel consumptions similar to those obtained with water-cooled engines are now possible, but the oil consumptions are just about twice those for the standard water-cooled types. Water-cooled radial engines have been built, such as the Salmson, made in France, but there does not seem to be any particular value in such designs.

The rotary type of engine was much used before the war, but was rapidly discarded with the increasing demands for power, since the crankshaft speed of such an engine is limited by centrifugal force. Therefore, it was necessary to use extremely large cylinders to obtain even reasonably high powers at the restricted operating speed. Small rotary engines were limited to from 1200 to 1400 r.p.m. This type of engine has now practically disappeared. Other arrangements of multi-cylinder engines

have been used, such as a so-called W-type with 12 and 18 cylinders, but the weights and widths of such engines do not warrant their use except for large powers in military work, and their complication tends to preclude their becoming popular for commercial work.

It seems almost advisable to restrict the number of cylinders to 12, as a maximum. If more power is required than can be secured from this number in a single unit, more units should be added. The situation is becoming practically identical with that faced by marine engineers, and we find that they have concluded it is more satisfactory to use several power units, rather than tie up their entire power in a single unit. It may be very alluring to the plane designer to consider 2000 hp. in a single unit, but two 1000-hp. units are very much more likely to bring the ship home. Several power units can be utilized for very large commercial ships, if centrally located in power nacelles. In this case they can be arranged to drive separate propellers, or connected together in such a way as to deliver their power to a common shaft. In the case of dirigible work the former arrangement is preferred. The problems involved in working out the latter arrangement are yet unsolved, the principal difficulty being that a propeller tends to turn as a flywheel at a constant velocity, whereas the various engines connected to it through the gears do not synchronize, and thus load the gearing intermittingly with disastrous results. Considerably fewer problems are involved if each engine has its own gearing and its own propeller.

Variations in Engine Characteristics

It is desired to give definite values to certain engine characteristics and to vary these values between limits, to determine, primarily, what the effect will be on the performance of an airplane. In such a discussion it is necessary to consider overall dimensions, engine weight per horsepower, fuel economy, cooling economy and altitude performance of the engine as factors. In general, overall dimensions will affect the maneuverability of the airplane, the parasite drag of the fuselage group and vision. These factors apply particularly to airplane designs having a single engine installed in the fuselage, for either military or commercial use.

The tendency of engine design toward radial or multiple-bank types is governed to a large extent by the desire to furnish short-coupled compact units. The application of such engines to airplane design has as its object increasing the maneuvering ability of the airplane. This question arises particularly in reference to engines for pursuit planes, and in the past has received much attention in the new development of such types of engine. It is true, all other things being equal, that the airplane having the greatest concentration of mass will prove to be the most maneuverable; but this consideration is only one in the very complex study of airplane stability. It will be remembered that maneuverability and stability are related, in that maneuverability will be most pronounced under conditions of neutral stability. If the airplane is designed to be highly stable, it will be stiff and will strongly resist rapid changes in flight attitudes, which is really a measure of its maneuvering ability. Concerning the airplane alone, the size and position of the lifting and control surfaces, the proportions and distribution of keel surfaces, the balance of the airplane and perhaps also the influence of different speed ranges on the airfoil surfaces, all have their bearing on the resulting ability of the airplane to maneuver. The effect due to mass concentration as influenced by engine dimensions, within reasonable limits, is probably the least important of these several factors. To bear out these assertions we can refer to that rather hackneyed example of certain of the German pursuit airplanes which were designed around a heavy vertical six-cylinder type of engine and yet possessed to a remarkable degree speed in maneuvering and readiness of control. These features were undoubtedly due to the aerodynamic characteristics the designers were able to derive from the choice and disposition of their lifting and control surfaces. There is much need of further experimental research in aerodynamics to develop practical data that can be put at the disposal of the practising airplane designer to assist him in the positive development of his design to a prescribed condition of stability.

We can consider properly the influence of the engine on the drag of the fuselage as increasing that drag when engine dimensions protrude beyond the usual fuselage lines. To complete this factor, the resistance offered by the cooling element should be considered also. For the water-cooled engine we must add the drag of the radiator. For the air-cooled engine we must allow for the high drag caused by protruding cylinders. An example is chosen of a design having about 375 hp. Two water-cooled engines are considered, one of which fairs readily into the fuselage lines, the other has protruding cylinder-blocks. One air-cooled engine is considered. The assignment of a proper drag coefficient is very difficult in this latter case due to interference to air-flow between cylinders. The total frontal area has been proportioned arbitrarily between cylinder shapes of high unit-drag and fuselage shape of minimum unit-drag. It is believed that the proportions chosen probably favor the design. The following relations are based on the usual formula:

$$D = D_c A V^2$$

In which

D = the drag
D_c = the pressure in pounds per square foot per miles per hour
A = the area in square feet
V = the speed in miles per hour

The values of $D_c A$ are determined, as they are directly proportional to the drag, and are shown in Table 1

TABLE 1—VALUES OF D_cA

Parts	Values of D_c	Values of A	Average D_cA	Best D_cA
Water-Cooled Engine				
Best fuselage	0.0006	10.75	....	0.00645
Average fuselage	0.0008	9.25	0.0074	....
Radiator, 9-in. core depth	0.0014	2.00	0.0028	0.00280
Total for fuselage group			0.0102	0.00925
Air-Cooled Engine				
Cylinders	0.0030	4.00	0.0120	....
Fuselage	0.0004	5.25	0.0021	....
Total for fuselage group			0.0141	

From these data we can determine that for water-cooled engines the drag of the fuselage group may be increased by about 10 per cent when the engine shapes are poorly adapted to usual fuselage lines. For a large radial engine this value may be as high as 52 per cent. The drag of the fuselage group for pursuit types of airplane will be 30 per cent of the total drag. This means that the total drag of the airplane will be increased, considering best water-cooled engine shapes as a base, about 3 per cent for poorer shapes of water-cooled engine and 16 per

cent for air-cooled engines. This increase in total drag will reduce the fineness of the resulting design, and so reduce the high speed. The effect will be of importance in military types, because of the tactical value of maximum speed. It will be important in commercial designs also, because of its effect on mileage obtained for a given fuel-consumption. The figures noted for the air-cooled design indicate a loss in high speed of 5 per cent, compared to best water-cooled design, which is an appreciable amount. The term "fineness" refers to the aerodynamic efficiency of the airplane; it is a function of L/D, the lift-drift ratio.

The subject of vision will be passed over briefly as it is very difficult to isolate the effects of engine size alone on a given vision. The design of the exhaust-manifold plays as conspicuous a part in obstructing vision as do cylinder-block positions. Furthermore, the engine is located at a point which is naturally blind because of the presence of the fuselage, and an increase in the blind area due to added engine interference will be comparatively small. This is rather remarkably shown in designs around the larger types of radial engines, such as the 375-hp. size, where a careful positioning of the pilot will result in very little added interference to vision. Cylinders Nos. 2, 3, 8 and 9 will be obstructing vision to some extent but their interference is of minor importance.

Reviewing briefly, we have pointed out that overall dimensions affect airplane maneuverability but that, within reasonable limits, their importance is probably secondary to other factors relating more directly to aerodynamic design. Extreme maneuverability is, in any event, a specialized characteristic required primarily of military pursuit airplanes. Overall dimensions, and particularly the form of engine design, as to whether it is water or air cooled, will influence appreciably the high

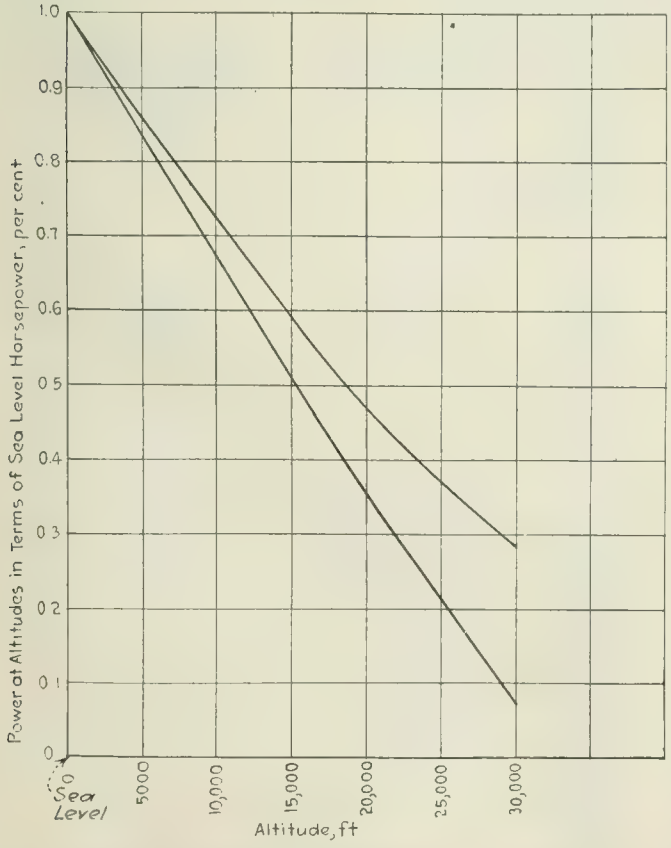


FIG. 1—VARIATION OF ENGINE HORSEPOWER WITH ALTITUDE AT FULL THROTTLE

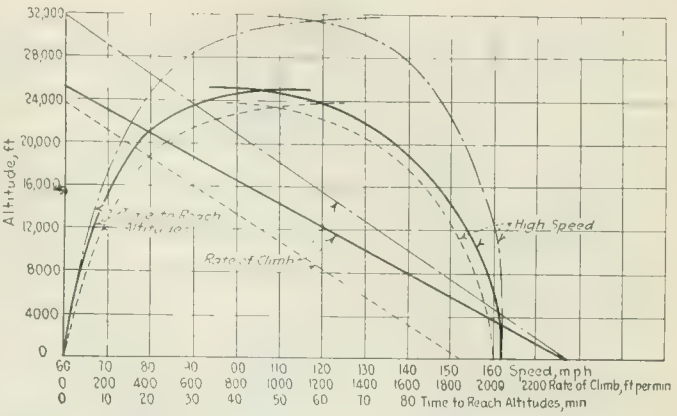


FIG. 2—RELATIVE PERFORMANCE OF TWO AIRPLANES IN WHICH THE ENGINE WEIGHT, COOLING ECONOMY AND THE PERFORMANCE OF ENGINE AT ALTITUDE VARY

speed obtainable for a given design. The importance of this characteristic is both military, for tactical reasons, and commercial, for reasons of operating efficiency. Overall dimensions have less effect on vision than usually is thought to be the case. Vision is governed not only by the extent of the obstructing bodies but by the positioning of the pilot with respect to these bodies.

The factors of engine weight per horsepower, fuel economy, cooling efficiency and engine performance at altitude, will be considered together as, in each case, their influence is similar as affecting the general flying performance of an airplane. In questions involving powerplant weight, it will be impossible to cover in detail the full range of ratios of this weight to the total weight as given by various sizes of airplane. It is necessary to tie down to one certain point in this range, which has been done in the examples chosen to illustrate these points.

Fuel economy and its effect on the total weight of the fuel carried has more bearing on long-flight duration than engine weight. We can assign the limits for these two factors as being engine weight and fuel economy without further detail and with a reasonable degree of accuracy. Assume that the engine weight will be increased 1 lb. per hp. and that there will be a reduction in fuel economy of 0.1 lb. per hp-hr. With such values it will be seen that a flight of 10 hr. is required to make fuel economy of greater importance than engine weight. This example, although crude, has its value as indicating rather clearly that engine weight will always be the important factor in airplane design, but that fuel economy will usually be of more importance in airship design. This, of course, assumes that the airship will be the medium of transportation for air-travel covering great distances. An exception may be found in certain special heavy-duty long-distance bombing or transport airplanes. The commercial airplane will usually find it much more advantageous to make relatively short hops, thus allowing the proportion of pay-load to fuel-load to be as high as possible.

To indicate the effect of engine weight per horsepower and cooling economy on airplane performance resort is made to hypothetical airplanes A and B and the result is shown in Table 2. Airplane A is taken as a standard. Airplane B differs from airplane A only in the use of an engine of greater weight per horsepower and one which will require $\frac{1}{3}$ more radiator cooling capacity than the engine for airplane A. The weights for powerplant are bulked and denoted by X. The weights of the structure complete, including the pilot, controls, instruments and the like, are bulked and denoted by Y, which equals 0.892

X. The value of Y in terms of X has been determined by obtaining the average figures given by several accomplished designs. The value of Y for airplane B, 1277 lb., is not 0.892 X, as airplane B is geometrically identical with airplane A. An increase in weight has been allowed which is assumed to hold the structural strength of the two airplanes the same. The characteristics on which the performance of airplanes A and B are dependent are shown in Table 3. The reduction in "fineness" has been based on the reduction in the L/D-ratio for the airplane, as affected by the increase in drag due to the increase in radiator size required.

TABLE 2—HYPOTHETICAL AIRPLANES COMPARED

	Weight of Airplane A, lb.	Weight of Airplane B, lb.
Inclusive of Engine, Engine Water, Radiator and Water, and Propeller	840 (2.1 per hp.)	1,040 (2.6 per hp.)
Gasoline, Lubricating Oil and Tanks	503	503
X	1,343	1,543
Y	1,192	1,277
Total Load	2,535	2,820

TABLE 3—CHARACTERISTICS ON WHICH PERFORMANCE DEPENDS

Characteristics	Airplane A	Airplane B	Airplane C
Total Weight, lb.	2,535	2,820	2,535
Area, sq. ft.	280	280	280
Engine Power, hp.	400	400	400
Weight, lb. per sq. ft.	9.05	10.08	9.05
Weight, lb. per hp.	6.34	7.05	6.34
Fineness, deg.	115	113	115

Before developing these performances we will consider the effects of engine performance at altitude. Airplane A is again the standard. Airplane C is powered by an engine of weight per horsepower and cooling economy similar to those for airplane A, but its altitude performance is according to the data given in Table 4, and Fig. 1, under engine No. 2. The characteristics on which the performance of airplane C is dependent are given in Table 3. The engine altitude-performance for airplanes A and B is according to the data given under engine No. 1, taken from two actual engine performances. The results of the performances developed for airplanes A, B and C, are given in Table 5 and are shown graphically by the curves of Fig. 2.

This study, see also Figs. 1 and 2, derives a means for measuring the effects on the complete performance of the airplane of increased weight and of increased drag, as governed by the engine design, and of better altitude performance of the engine. By thus increasing the total weight of the airplane 11 per cent and by decreasing its L/D-ratio 3 per cent

(1) The rate of climb is reduced by values of from 22 per cent at sea level to 40 per cent at a 20,000-ft. altitude

(2) The time to climb is increased by values of from 29 per cent at 5000 ft. to 30 per cent at a 20,000-ft. altitude

TABLE 4—EFFECTS OF ENGINE PERFORMANCE AT ALTITUDE

Altitude, ft.	Engine No. 1, per cent	Engine No. 2, per cent
Sea Level	100.0	100.0
5,000	83.4	85.8
10,000	67.7	72.1
15,000	50.8	59.1
20,000	34.9	47.1
25,000	21.5	37.5
30,000	7.6	28.5

TABLE 5—RESULTS OF PERFORMANCES DEVELOPED

	Airplane A	Airplane B	Airplane C	B Performance Reduced to Percentage of A Performance	C Performance Increased to Percentage of A Performance
Weight, lb. per sq. ft.	9.05	10.08	9.05		
Weight, lb. per hp.	6.34	7.05	6.34		
Fineness, deg.	115	113	115		
Engine	No. 1	No. 1	No. 2		
Speeds, m.p.h, at altitude, ft.:					
Sea level	162	160	162	98.70	100.0
5,000	161	158	161	98.70	100.0
10,000	156	153	161	98.00	103.0
15,000	149	146	158	98.00	106.0
20,000	136	131	153	95.00	112.5
25,000	103	113 (23,000 ft.)	145	.....	141.0
30,000	...	...	131	.....	.....
Absolute Ceiling	94	98	107	.....	.....
Ceilings, ft.:					
Service	24,000	22,400	30,400	93.25	126.8
Absolute	25,150	23,750	31,800	94.50	126.5
Rate of Climb, ft. per min.:					
Sea level	2,340	1,840	2,340	78.50	100.0
5,000	1,870	1,450	1,970	79.10	105.3
10,000	1,410	1,060	1,600	75.70	113.5
15,000	940	670	1,210	72.00	128.8
20,000	480	290	860	61.70	179.2
25,000	...	...	500	.....	.....
Time to climb, min.:					
5,000	2.38	3.07	2.33	129.00	97.8
10,000	5.45	7.07	5.14	129.70	94.3
15,000	9.75	12.90	8.66	132.40	88.7
20,000	17.01	23.84	13.49	140.00	79.2
22,400 Service Ceiling of B	.....	37.05	.....	.....	....
24,000 Service Ceiling of A	33.15	.....	.....	.....	....
25,000	.....	.....	20.92	.....	....
30,000	.....	.....	39.03	.....	....
30,400 Service Ceiling of C	.....	.....	44.55	.....	....

(3) The ceiling is reduced by about 6 per cent
(4) The high speed is reduced by values of from 1 to 5 per cent. This loss in high speed is due almost entirely, however, to the reduced fineness of the airplane

By varying the relative percentages of power output at altitude from equal values at sea level to a relative increase of 375 per cent at 30,000 ft.

(1) The high speed is increased by values of from 0 per cent at sea level to 13 per cent at a 25,000-ft. altitude
(2) The ceiling is increased by 27 per cent
(3) The rate of climb is increased by values of from 0 per cent at sea level to 79 per cent at a 20,000-ft. altitude
(4) The time to climb is reduced by values of from 2 per cent at 5000 ft. to 21 per cent at a 20,000-ft. altitude

The value to military airplanes of these increases in performance are unquestionable, especially as they relate to climbing ability and ceiling because they are the more pronounced. The tactical advantage which the fighting pilot will have in an ability to out-climb and out-reach his opponent is well understood. Commercial types of airplane will benefit most in an ability to substitute for unnecessary dead-load or dry weight, the same weight in the form of pay-load. The value of engine efficiency for commercial work will be particularly great in the ability it gives to maintain higher speeds at cruising altitudes, and so increase mileage for a given weight of powerplant and fuel consumption.

We have shown what increases in airplane performance can be expected through variations in engine characteristics from average to best values. If still greater increases are required, either to put military aviation on a higher plane or to permit commercial aviation to be established on a sound economic basis, we cannot expect to derive such increases simply by further refining of present types of design, but rather we must develop other forms of design, perhaps radical in nature, which will accomplish the work of flying more efficiently than our present types of apparatus can.

Characteristics for a High-Speed Airplane

Before leaving the subject of engine and airplane characteristics, it will be of interest to make an estimate of what these characteristics must be for a very high-speed airplane. Popular interest centers around the 200-m.p.h. mark. We often speak as though we can attain that speed simply because we desire to do so. It is well to realize just what the requirements are in order that an airplane, designed to our best usual practice, can fly 200 m.p.h. in bona-fide level flight. The results of our last Pultizer Trophy Race serve to give us a basis on which to build an estimate. The characteristics of the actual airplane are given in Table 6.

TABLE 6—CHARACTERISTICS OF THE ACTUAL AIRPLANE

Weight, lb.	1,875
Wing Area, sq. ft.	250.5
Engine Power, hp.	367
Assumed Propeller Efficiency, per cent	80
Weight, lb. per sq. ft.	7.50
Weight, lb. per hp.	5.10
High Speed, m.p.h.	170.25
Wing Section, R.A.F.	No. 15

A = Wing Area, sq. ft.
V = High Speed, m.p.h.
$L_c = 1875 \div [250.5 \times (170.25)^2] = 0.000259$
$L = L_c A V^2$
$i = -0.2$ deg. = corresponding angle of incidence
$D_c = 0.000032$
$D_w = D_c A V^2 = 0.000032 \times 250.5 \times (170.25)^2 = 232$ lb. = Wing Drag
$D = (367 \times 0.80 \times 375) \div 170.25 = 647$ lb. = Total Drag
$\frac{DV}{375}$ = Engine horsepower times propeller efficiency
$D - D_w = 415$ lb. = Parasite Drag
$(D_c A)_p = 415 \div (170.25)^2 = 0.01432$ = Parasite Drag Unit
$D_p = (D_c A)_p V^2$

The actual airplane was of standard size and wing-loading and did not represent suitable wing-area, fuselage dimensions or chassis size for a light racing airplane. Therefore certain reductions in size are assumed which are to be expected in a design developed solely for speed purposes. Assuming that the weight loaded is 1740 lb., taking account of the reduced dimensions throughout, and that the landing speed shall not exceed 65 m.p.h., the maximum L_c for the wing is 0.0030 lb. per sq. ft. per m.p.h. Then,

$A = 1740 \div [0.0030 \times (65)^2] = 137$ sq. ft.
$L = L_c A V^2$
$L_c = 1740 \div [137 \times (200)^2] = 0.00318$ lb. per sq. ft. per m.p.h. at high speed
$i = +0.1$ deg. = corresponding angle of incidence
$D_c = 0.000033$
$D_w = 0.000033 \times 137 \times (200)^2 = 180.8$ lb.

For this type of airplane, the distribution of drag at an angle of 0 deg. is of the order shown in Table 7.

TABLE 7—DISTRIBUTION OF DRAG, $i = 0$ DEG.

	Standard Design	Drag Percentage	Special Design	Reduction Factor	New Percentage
Wings, lb. per sq. ft.	7.5	30.0	12.7	....	....
Wind Bracing	2-Bay	7.2	1-Bay	0.60	4.32
Fuselage, sq. ft.	11.5	27.7	8.63	0.75	20.78
Chassis	....	22.6	....	0.75	16.95
Tail Surfaces	....	12.5	No reduction	1.00	12.50
Percentage of Drag which is Parasitic		70.0	....	....	54.55

Under such conditions the parasite-drag unit will be reduced to

$54.55/70 = 0.78$ of its original value
New $(D_c A)_p = 0.01432 \times 0.78 = 0.01118$
$(D_c A)_p V^2 = 0.1118 \times (200)^2$
$= 447.2$ lb. = Parasite Drag
$D_w = 180.8$ lb.
$D_p + D_w = 628$ lb. = Total Drag
Required Horsepower = $(628 \times 200) \div (375 \times 0.8) = 418$ hp.
Weight, lb. = 1,740
Area, sq. ft. = 137
Engine Power, hp. = 418
Weight, lb. per sq. ft. = 12.70
Weight, lb. per hp. = 4.15
High Speed, m.p.h. = 200

One can well imagine the care required in the design of both engine and airplane to meet this power, weight and fineness.

The matter of the value of retracting the chassis immediately presents itself. A study, similar to the one already presented, has been carried through on the basis of eliminating completely the chassis resistance. The assumptions that were made and which are considered to be fair are (*a*) an addition of 60 lb. of weight, to cover the retracting mechanism complete, and (*b*) that the fuselage dimensions are not altered to provide suitable space for the retracted chassis. Under these condi-

tions the required power becomes 384 hp., which is more definitely within the range of possible design limits.

Powerplant Installation

Cooperation between the builder of engines and the constructor of airplanes is the most essential factor required in the development of successful and serviceable installations of powerplants. The aircraft industry is at present divided into these two well-defined activities. Each has its own distinct engineering problems and, naturally, the viewpoint of one is not identical with that of the other when considering the requirements of the industry as a whole. However, the interest and advantage of both are reasons for finding common ground in solving the engineering problems incidental to the installation of the powerplant. It is essential that the airplane and the engine shall be assembled into the powered airplane with due consideration given by both parties to the many complex problems involved.

The airplane designer should consider the detailed requirements of the engine he is using as soon as he makes his first study of the general arrangement of his design. Simplicity in the design of engine systems is in itself an assurance of their dependability, and a simple design can be effected most readily by grouping all items relating to the engine as near to it as is practicable, without interfering with accessibility. The necessary cooperation between engine and airplane designers must be asserted during the design periods when all controlling factors can be understood thoroughly and considered, and suitable compromises reached. It is well known that a completed design, if improperly executed, is very difficult to change and correct. When the necessary changes are undertaken they are always costly and often ineffective, due to many other limiting factors.

Before developing designs of powerplant installations it is necessary to know what the exact capacities required by the several systems are, and these capacities must be provided if the engine is to operate at maximum power. It is the function of the engine builder to know what the particular installation requirements for his engines are. He must be prepared to recommend suitable types and capacities for all accessory equipment. Recommendations of this sort will be governed largely by the type and characteristics of the airplane involved, and general specifications covering any and all cases cannot be written satisfactorily. For this reason each design must receive its special study before accurate and most applicable recommendations can be offered. This study must necessarily be gone into jointly by the airplane and the engine builders. The latter will probably supply a complete powerplant eventually rather than an engine which can be installed as a unit in a given airplane design. When airplane sizes have increased sufficiently to allow complete engine nacelle designs, such a procedure can be wholly practical.

Propellers, although their design is based largely on aerodynamic calculations, belong primarily to the powerplant group. The development of propellers for military airplanes has been dependent largely on the ultimate performance desired of these airplanes. The engine to be used affected the propeller design principally in determining the speed at which the propeller should turn and the maximum power it would need to absorb at that speed. Economy in engine operation is very greatly dependent upon the values of running speed and developed power for that speed. To realize greatest economies in engine operation, propeller designers must, in the case of types of airplane in which operating economy is paramount, consider the ability of the engine throughout its full power range, rather than only its maximum performance.

A most important consideration in the design of powerplant installations is that of engine supports or mounting. It is not only necessary that the mounting provide a suitable support for the engine, but its design must also be arranged to permit accessibility to the essential parts of the engine, such as pump connections, strainers, relief valves and magnetos. This will require a consideration of these points when determining the position of the truss members or the type of design. For instance, the use of a veneer skin at the engine section, which is designed to carry shear stresses, usually will result in a poor arrangement because suitable handholes cannot be cut without interfering with the structural characteristics. The ideal design at the engine section will provide a cowling which can be removed completely, exposing the engine so that adjustments, repairs or renewals, can be made readily. In this connection it is well to remember that any part of the powerplant which is difficult of access will receive a minimum of attention, and this may lead to engine failures in the air. It is necessary also that the engine shall be designed to expose all parts requiring frequent inspection. These questions are receiving and will continue to receive very careful attention in engine design.

The use of metal in engine frames will always hold a prominent place. The design of steel tubular A-frames is common, and such designs are structurally efficient. Frames developed from steel plates pressed into channel-sections also are becoming more common. Many practical difficulties are involved in this latter class, which result often in approximate failure of the design. In developing the channel sections designers may provide too little flange-depth and area, with the result that the sections are very inefficient about one axis. These frames usually are built in limited quantities which do not permit the development of suitable dies for forming the shapes. Forming is largely accomplished by hammering rather than by pressing. Anything but extreme care in this work will result in deformations of the sections due to dents and other unevennesses. This will cause local losses in strength properties. Gages used are often much too light. Gages common in tubular sections cannot be applied to other sections without further thought, for it must be remembered that the tube is a more efficient structural section than other forms.

The selection of suitable gages brings up intimate problems of design. It need hardly be stated that the engine frame cannot be designed for static loads only, and that due consideration must be given to the running stresses of the engine that are transmitted to the engine frame. It is necessary that the designer appreciate what these stresses are; thrust, torque and forces set up by vibration. He must develop his truss to accommodate the magnitude and direction of application of the forces involved. Without some special means for absorbing reversing stresses or those that vary rapidly in their intensity, rigidity of mounting is essential. Some supports will be developed with sufficient local strength and rigidity, but the structure between the engine and the truss anchorage will not have a proportionate amount of strength. Such design is equally faulty with that which is of insufficient strength and rigidity throughout. For single-engine installations it seems advisable to develop a rigidly jointed structure comprising the engine-bed and fuselage to the rear support of the wing, including the

center-section trussing and perhaps the chassis truss also. The importance of suitably mounting the engine cannot be overestimated. Airplane designs which have excellent flying characteristics but are designed poorly in the engine section and thus cause frequent failures of structural parts, will suffer an unnecessary loss in reputation because of these faults, which are largely due to a lack of appreciation of design requirements.

If an engine is to operate continuously at maximum power, it must have adequate cooling and be provided with an efficient means for temperature control. The cooling requirements of air and water-cooled types of engine are probably wholly different, but our experience with stationary air-cooled engines has been so meager to date that we are hardly qualified to write exact specifications for them. However, through winter flying experience had in different countries, particularly in Russia, where very low ground-temperatures exist, it has been found that air-cooled engines are the only type that can be operated successfully under such conditions. Rotary engines were used. The principal difficulties centered around the ability to start the water-cooled type before the water froze, even though it was supplied to the engine at a boiling temperature. Past experience with rotary engines has indicated with equal clearness that the air-cooled engine is heavily handicapped when operating under conditions of very high ground-temperatures, because of its inability to deliver maximum power required in taking-off. The need of the air-cooled engine for temperature control is an open question. There is nothing peculiar about this type to lead one to believe that it will not require such control. Radial engines have been flown by some foreign builders, largely without the provision of shutters. However, we do not know whether their engines operate efficiently at any and all temperatures, and so cannot judge whether this operation without temperature control is really successful.

A given design of water-cooled engine will require a definite capacity of cooling element when operating under the conditions prescribed by the performance of an airplane. The most important requirement in the design of the cooling system is the provision of the required size of radiator. Any effort to reduce the airplane drag by cutting the radiator size below the required capacity is decidedly short-sighted. Since the airplane designer will control largely the choice of position for the radiator, he must appreciate fully the advantages to be gained from a proper selection of core, from the standpoint of both water-flow and cooling efficiency. A detailed study of cooling systems is much too broad a subject to cover in this discussion. It is well to bring out, however, that a suitable choice of radiator type and position can result in the saving of about 35 per cent in the weight of this unit and about the same reduction in its drag.

The oil system for a given installation can be very simple. Generally speaking, it is unnecessary to include a special radiator for cooling the oil. Cooling can be effected more economically and the system can be simplified and lightened by exposing the oil-tank to a free flow of air. The design of the tank should insure that the oil is discharged against this exposed surface, and that the inlet and outlet pipes are arranged with respect to one another so as to insure complete circulation in the tank.

Nothing is more essential in the design of a fuel system than that it shall be direct and positive. Simplicity is required not only in the general arrangement of the system but in the means employed to induce flow through it. Because of the hazards of military flying, we find specifications written requiring the inclusion of two or more distinct systems. Such design is however not applicable to the needs of commercial flying. Both services will benefit by the use of absolutely reliable equipment for the fuel system, and the problem of supplying suitable accessories is now a serious one before the industry. A fuel-pump can and should be an integral part of the engine. Because of the extreme variation in the designs of fuel systems, this pump must have wide limits of ability. These limits will be well defined by the engine builder, and the system must be built to them. In conjunction with the pump there will be need for valves, strainers and the like, the design or type of which should be specified by the engine builder. Engine design will permit as much of this apparatus to be integral parts of the engine as is practical. All piping that can be made a permanent part of the engine should be installed so that only direct connections from the supply to the pump, valves or strainers will be required.

The proper functioning of the several systems is dependent on two things; first, a simple and correctly conceived design and, second, an ability to give these systems the mechanical attention they require. This latter ability is dependent on the skill of the designer to arrange his systems so that their essential parts are open to inspection, repair or renewal. Designers' attention is too often devoted to the problems of close assembly meant to conserve space, and not to the maintenance problems which will develop as soon as the airplane is in service. The value of extreme efforts to secure short-coupled airplane designs has already been questioned. The advantage secured by an airplane having features permitting easy maintenance is unquestionable. It must always be remembered that the value of a design is not determined as much by its ability to develop a performance, as by its ability to continuously and consistently give that performance; this latter condition can exist only when routine mechanical attention can be given the powerplant as a whole, with a minimum amount of effort and delay.

Summary

It is desired to emphasize the following points by summarizing them. We have not reached the limiting size for any type of engine as regards the maximum power available. No increase in engine performance can be expected unless new materials of construction, new fuels or new cycles of operation are made available. Continued development will refine the practices of the art and result in bettering the life of the engine and the service it renders, rather than its performance. Therefore, increased airplane performance must be secured mainly by improvement in airplane design. Great advance seems to be possible in this direction. One reason for the tremendous powerplants available for airplanes has been the effort to secure performance by brute strength. Absurdities can soon be reached if this trend of development continues. It is certainly worthwhile to consider what can be done with a reasonable-sized power-unit, by altering the design of the airplane. As shown in the last Pulitzer Trophy Race, excessive horsepower is not necessary to secure high speeds. The next few years should see a reduction in the power demanded of pursuit engines.

It is high time that attention be given to a most important problem, the fuel mileage obtainable from a given airplane. It is unquestionably true that the average person could not afford to operate some airplanes, even though he might be able to purchase one, because of the

poor mileage secured from a gallon of fuel. This is an essential consideration for commercial work, due to its effect on the profits of an operating company, and should be given study by the military authorities also, on account of the effect it has upon the quantities of fuel required in case of hostilities. This is, to our minds, the best and most obvious reason why the power requirements for aeronautical powerplants should be reduced rather than increased. It is not commercially possible to build so many power units within a given range. Airplane designers must be satisfied with fewer units, if we are to commercialize the business.

It is believed that the effect of engine dimensions on maneuverability is largely overestimated. The reason that popular comment is so often to the effect that the engine is the most important factor is the fact that there is no ready means by which the aerodynamic qualities of the airplane affecting maneuverability can be thoroughly analyzed and visualized. For similar horsepowers engine type rather than overall size will have the greatest effect on the parasite drag of the fuselage group. The efficiency of the cooling-element design for water-cooled engines is considerably better than that for air-cooled engines. Between practical limits, the effects on the performance of the airplane of variations in the values of engine weight per horsepower, of cooling efficiency, of fuel economy and of altitude performance of the engine are very pronounced. The demands of super-performance in military designs and greatest operating efficiency in commercial designs will require the development of engine types which are most favorable in these respects. The relative importance of the factors involved is governed by the particular service for which the airplane is designed.

Problems of powerplant installation are centered about the need of a close cooperation between the builders of airplanes and engines. The requirements of each system of installation can be met only by acquiring a correct knowledge of what these requirements are and satisfying them fully. A study of the engine mounting in complete detail, developing the truss system to accommodate all of the engine forces involved, both static and dynamic, is a most important requirement in insuring a successful installation. Simplicity and practicality of design and the suitability of the accessory equipment used are most essential in the development of the several powerplant systems. The development of the complete powerplant installation must be made with a view to permitting the greatest possible degree of service accessibility. Only in such a way can the proper mechanical attention be assured for the powerplant. The fact must not be lost sight of that the industry is in a formative period and for this reason we must expect to spend a tremendous amount of time and money in research. We cannot standardize without the necessary knowledge, and we cannot obtain that knowledge without research.

LOOKING INTO A GASOLINE-ENGINE CYLINDER

THE first tool used by the investigator is usually the eye. He sees a thing happen and the first step in his investigation is likely to be the obtaining of a telescope, microscope or something to enable him to see more clearly. In the development of the internal-combustion engine, however, visual observation of the combustion has played a minor role. To be sure, early investigators did provide apparatus that permitted them to look into the cylinder while the engine was operating, but little has been done in this direction with engines operating at the high speeds of the present-day automobile types. Interest has centered in what an engine could do rather than how it did it. As a result, measurements of brake horsepower and fuel consumption have been deemed of first importance.

At the present time, the cry for fuel conservation has reawakened interest in the nature of the combustion in the cylinder. Glass induction-systems have disclosed how satisfactorily, more often how unsatisfactorily, the fuel has been prepared for combustion. Analyses of the exhaust gases have shown how completely, more often how incompletely, the charge has been burned. Admitting that it is important to study the preparation of the fuel for combustion and the results which are evident after it has taken place, an actual study of conditions during combustion should surely be worthwhile. This has been accomplished in connection with the study of combustion in the one-cylinder Liberty engine at the Bureau of Standards. In conducting this work use is made of a spark-plug shell which has been adapted to receive a circular section of glass intended to serve as a window in the cylinder. This assembly can be used in place of either spark-plug in the ordinary aviation cylinder, but in this instance an additional boss has been welded to the cylinder in order that conditions might be observed with both plugs firing. Its use was satisfactory in that changes in flame color due to changes in air-fuel ratio were easily discovered. Since the entire combustion stroke is completed in 1/16 sec. at an engine speed of 1800 r.p.m., it is possible to see only the predominant color of the cycle by this means.

To make it possible to observe the combustion in its various stages, another device, a stroboscopic disk, was added. Its purpose is to permit the combustion to be observed during only a small portion of the stroke. Since there is one power-stroke for every two revolutions of the crankshaft, this disk is driven at one-half of the crankshaft speed. The flame is observed through a slot in the disk, the length of the slot governing the length of the portion of the stroke studied. Provision is made for altering the angular relation of this slot to the crankshaft so that any interval of the cycle and hence any stage of combustion can be studied.

Observations made possible by this apparatus are not likely to replace any of the more usual measurements. They may, however, prove, and in fact have proved of considerable value in research work of the nature described by permitting observations of the duration of luminous flame during the power-stroke, the characteristic differences in color and brightness at different phases of combustion and their variation with changes in ignition timing, mixture ratio, compression pressure, etc. One observes, for instance, excessively bright flashes of flame of extremely short duration accompanying the phenomenon known as fuel knock or detonation. The cause for this phenomenon is, of course, not revealed by usual observation.—Bureau of Standards News Bulletin No. 49.

Standardization as Brought About by the Society of Automotive Engineers[1]

By B. B. Bachman[2]

THE development of commerce from the dawn of history has been accompanied by the creation of standards, using the term in its broadest sense. The first were standards of measure to permit of the interchange of commodities, followed by standards of money as the use of money and credit displaced bartering. The growth of manufacture on a large scale, as distinguished from the making of goods to order, has brought about standards of sizes, as in clothing. The development of machinery to displace manual labor has brought about the adoption of standards for tools and equipment. It will thus be seen that unconsciously perhaps the crystallization of practice by continuous usage has been the means of creating standards which are used every day with so little thought as to their being or on what they were founded, that only the complete removal of them would give us an adequate conception of the absolute indispensability of these standards in our lives.

Time and again it has been pointed out that the automotive industry in the United States has reached its giant stature in so short a time as to be almost miraculous. The reason for this is manifold. Transportation has ever been one of the foremost needs of man, coupled with means of communication; any improvement in speed, dependability and comfort in transportation has met with instant acceptance and support by the public. The automobile, passenger car or truck, is primarily a means of transportation. Many have been the assertions by economists and others that the passenger car is fundamentally a luxury. Such assertions are, to my mind, refuted by the phenomenal growth of the usage of the automobile. The invention and development of the internal-combustion engine has made possible the creation of a light, compact prime-mover, which permitted the realization of the possibility of a transportation means for the individual over the public highways in the form of the passenger car and motorcycle, for merchandise by the truck, and later has satisfied the longing of man for the means of lifting himself above the earth and moving about without let or hindrance from the physical obstruction of mountain, stream and forest, and even the oceans which separate continents.

This marvel of mechanical science did not belong to us of America exclusively, however, and in many ways we were handicapped in the race to develop the automobile successfully from a curiosity to a point where it could be produced in quantities at prices which would put it within the reach of any but the plutocrat.

The successful solution of this problem lies in the art of quantity production of duplicate parts involving the use of machinery instead of men, and the interchangeability of parts and assemblies which facilitates and makes economical not only the manufacture of the article, but also its repair and maintenance. Carrying this thought to its logical conclusion, we arrive at the need for standards; and it is my opinion that the recognition of this need and the development and adoption of standards has been one of the most important reasons for the growth of the automotive industry. The industry was born coincidently with the beginning of the development of new methods of measurement, new machines and production methods. The men who started it were imbued with the pioneer spirit and would try once anything that looked promising, else they would never have started at all. In the beginning there was a great deal of rivalry and secrecy. Development was rapid and novelties introduced by one were copied or improved upon by others.

Beginning of Automotive Standardization

The old Association of Licensed Automobile Manufacturers was formed early in the history of the industry, but produced no real cooperation as realized today. Associated with this organization was the so-called Mechanical Branch, consisting of engineering and production representatives of the members of the Association, and while some progress was made in exchanging information among and creating standards for these members, such as the 7/8-in.-18 spark-plug thread and a series of bolt and nut sizes, the suspicion of the other fellow and his motives prevented a realization of all the benefits of cooperative endeavor.

Although this means of interchange of ideas existed, there were men whose vision reached out to a broader type of organization and a few of them got together and effected an informal organization in 1904 followed by the adoption of a constitution and the election of officers. These were A. L. Riker, president; Henry Ford, first vice-president; John Wilkinson, second vice-president, and E. T. Birdsall, secretary-treasurer. On the board of managers were H. M. Swetland, A. H. Whiting, L. T. Gibbs, H. P. Maxim, H. W. Alden and H. Vanderbeek.

From this beginning of the Society of Automobile Engineers, there was a gradual growth until in 1910 after the election of Howard Coffin as president, Coker F. Clarkson was secured as secretary and general manager and the beginning of a permanent office force effected. At the summer meeting in 1910, held at the Hotel Tuller, Detroit, the late lamented Henry Souther presented specifications for materials which were a revision of specifications which had been issued annually by the Association of Licensed Automobile Manufacturers. Later in this session discussion on the value of and necessity for standards culminated in the adoption of the policy looking toward the establishment of a Standards Committee, and this was effected later with Henry Souther as chairman.

Naturally the inauguration of such a policy was not a matter of unanimous consent. There were widely varying opinions, some of which have not been wholly harmonized today, and I feel I can do no better in presenting this phase of the subject than to quote from papers presented by Messrs. Souther and Clarkson.

[1] Presented at a meeting of the Automobile Accessories Business Association of Philadelphia, May 20, 1921.

[2] M.S.A.E.—Chairman of the Standards Committee, Society of Automotive Engineers, and chief engineer, Autocar Co., Ardmore, Pa.

Mr. Souther in 1912 presented his views as follows:

It is safe to say that all approve of some standardizing work and freely admit that some standards are possible. There is the class which believes that a standard, in order to be worth anything at all, must not be adopted or recommended until everything is known about the subject. In contrast, there is the class which seems to believe almost anything can be standardized and which would go to very great extremes in the matter. There is apparently a sharp division of opinion between these two groups. One believes that standardization should begin early in the history of an industry. The other believes that no standard is possible in an industry until such industry is so old that the probable changes in the proposed standard are few and far between. These views are diametrically opposite and require consideration.

Another view of a standard apparently taken by some contemplates the fact that a standard once adopted by the Society must be used by all its members or else they shall forfeit their rights to membership, or citizenship or something else not expressed. This is certainly not the case. A standard, in order to be accepted, must have so much merit that engineers or producers or executives will see good reason for its acceptance. Good engineering design may be the reason it is worthy of universal adoption; easy manufacture may be another reason why it should be adopted and become standard practice; and low cost is a reason why the business organization would say to the others involved that it must be adopted. As a matter of fact all three of these qualities will usually be found in any good standard. The adoption of a standard is not compulsory; it is voluntary.

There are many more details of an automobile that should not be standardized. To draw the line in a practical way between that which is fit material for standardization and that which is not, is the work of your Standards Committee and of the whole Society. Your committee will solve this difficulty satisfactorily, providing the members of the Society will come forward freely and frankly with whatever knowledge they may have on the subjects under discussion. A standard should certainly represent the collective knowledge of all concerned, rather than the narrow viewpoint of some one man or small group of men. The manner in which the Society of Automobile Engineers is attempting to arrive at proper standards is to get together all those interested in any way and promote such discussion as will result in some decision. Various interests must be involved. There are always at least two, the producer and the consumer. There may be several; for example, the producer of the raw material, the manufacturer who shapes it and finally, the consumer of the finished article. There is usually the sales interest between the other interests.

Mr. Clarkson's views along similar lines were presented in 1920 before the National Gas Engine Association, and are as follows:

One troublesome misconception of the standards we are discussing is that they are mandatory. Another is that they are manifestos of finality like standards of weight or measure. An automotive engineering standard is a thing that is considered, by men well qualified to judge, good or best for the great bulk of the manufacture in our field, to facilitate quantity production in the way I have indicated. The Society of Automotive Engineers has no way of enforcing the use of its standards except insofar as their merit is weighty. This is as it should be, and for a like reason the S. A. E. standards work has been successful. It has been demonstrated over a period of years that most of the standards can be reduced to practice by the great majority of manufacturers with marked benefit to themselves, as well as their customers; in fact, in all cases where the production is not really inherently special, or on account of large substantially identical previous production not incorporating the currently desirable standards. The latter condition is almost inevitably a matter of the relative importance of the past and the future to the manufacturer.

The Society of Automotive Engineers is not commercial in the sense that it can enforce its standards in an arbitrary way. It is commercial in the sense that its standards are of commercial value. The Society can conduct its activities on a somewhat broader and less partisan basis than a commercial organization. A commercial organization of manufacturers, proceeding as such, without giving effect to engineering questions as such, cannot, on account of competitive sales reasons, get as good results in the formulation of engineering standards as an organization like the Society can. In more than one instance that organization has established standards that have gone into general practice, after the representatives of the manufacturers directly concerned working together, or failing to work together, had been unable to establish them.

Standards should, of course, be canceled or revised when necessary. They should not, obviously, be promulgated originally unless there is sufficient evidence to assure their holding good for a properly long period of time. But the whole system should be conducted flexibly and not inflexibly.

Work of the Standards Committee

I do not feel that I need elaborate further on this, except to state that these views are a clear expression of the policy under which the Standards Committee has conducted its work. After a number of years of successful work, during which the growth of the Society was phenomenal, other organizations, recognizing the value of the Society in general, and the standards work in particular, became interested, with the result that in 1917 the Society of Automobile Engineers became the Society of Automotive Engineers and embraced, for purposes of fostering standards, the problems of the stationary internal-combustion engine, the marine and tractor interests, and aviation. From a small beginning with many problems of policy to solve, the Standards Committee has grown until for the current year there are 29 Divisions of the Committee, with a total membership of about 300, and a complete force under the general manager of the Society who devote their whole time to the work. Every endeavor has been made to conduct the work along the most representative and democratic lines, and furthermore, mere majority action is not allowed to carry through a proposal which a competent minority or even individuals oppose with well-founded objections. The results of the work have been highly satisfactory in both quantity and quality. There are at present listed in the S. A. E. Handbook 215 separate Standards or Recommended Practices, divided into 10 divisions, covering Powerplants, Electrical Equipment, Parts and Fittings, Materials, Transmissions, Axles and Wheels, Tires and Rims, Frames and Springs, Controls and General Information.

As to the value of the work, much can be said, but unfortunately conversation has never established anything. The proof of the pudding is in the eating; and to my mind the best evidence of the value of S. A. E. Standards is shown by the fact that, in spite of great criticism and even sharp antagonism on the part of many,

(*Concluded on page* 38)

Eliminating Crankcase Dilution by Manifold Development

By G. P. Dorris[1]

Semi-Annual Meeting Paper *Illustrated with* Photographs

About 1912 the gasoline began to carry heavy ends in such amount that the application of a hot-water jacket around carbureters and manifolds improved the operation of the internal-combustion engine. Then the heavy ends increased up to 1915 and 1916, when a further revision became necessary to provide still higher temperatures than were possible with the limit of 212 deg. supplied by the hot-water jacket. Exhaust-heated manifolds and hot-spots helped to maintain the same degree of efficient operation with the then increased heavy ends of fuel. About 1917 the heavy ends of the fuel sold as gasoline required such an amount of heat to vaporize them that the expression "crankcase dilution" appeared. Now the heavy ends of the gasoline have increased to a maximum boiling point of 446 deg. fahr. This has made it necessary to go still further in the direction of the heat application to get satisfactory results.

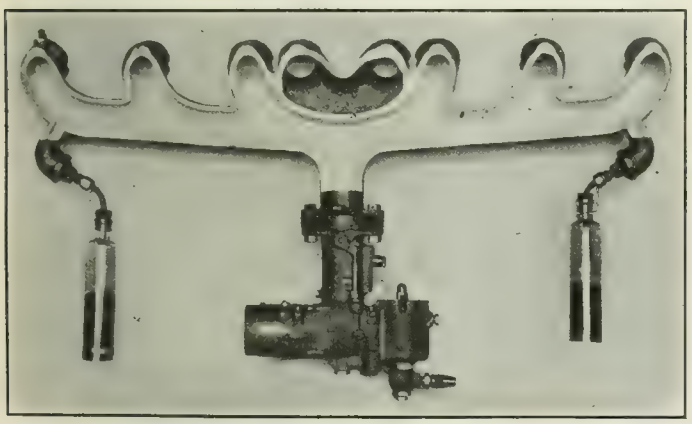


Fig. 1—An Admission Pipe of a Six-Cylinder Engine in Which the Two Exhaust Ports at the Center Form a Hot-Spot Immediately Above the Carbureter Inlet

Relative Heat-Absorption of Air and Fuel

In the development of the internal-combustion engine it has become evident that the application of heat to the fuel through hot air is only a mild method of heat application and very detrimental to the volumetric efficiency and power output. It soon became recognized that the application of heat through the air was not a method of sufficient intensity to get desired results, and on further investigation it was seen that the direct application of heat to the fuel is a more efficient method as the relative heat-absorption capacity of air and fuel is approximately in proportion to their weights; hence the desirability of the elimination of hot-air jackets and the introduction of direct fuel-heating devices.

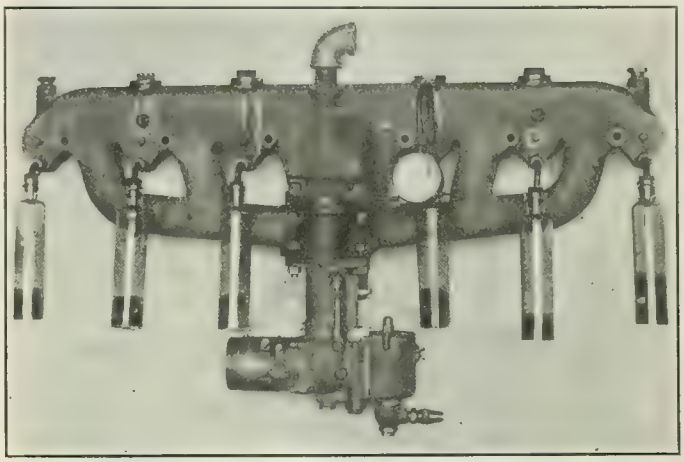


Fig. 2—An Improved Type of Manifold in Which the Admission Pipe Is Cast Integrally over the Exhaust Pipe thus Securing Better Vaporizing of the Heavy Ends

To the casual observer gasoline appears to be a definite fixed fuel not readily divided into several grades or degrees of combination of hydrogen and carbon. By subjecting this gasoline or fuel to a vacuum, it becomes evident that the vacuum readily separates the light ends from the heavy and gives a very satisfactory gas with a cold engine, which is very desirable in starting. Taking advantage of this fact, it is desirable to delay the delivery of the heavy ends of the gasoline until such time as the proper amount of heat can be applied to vaporize and pass

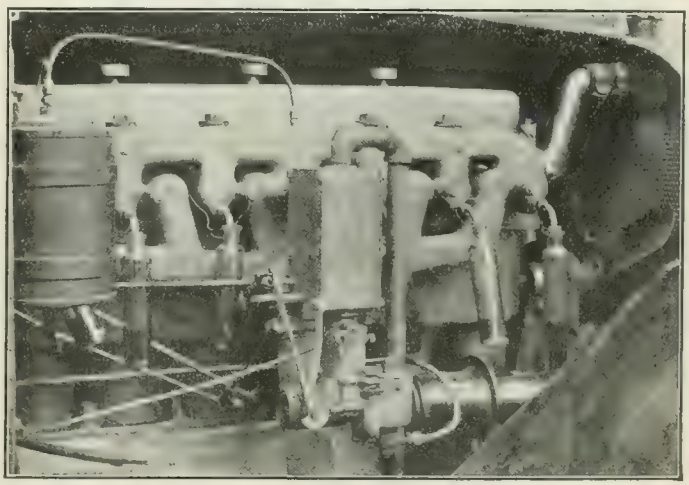


Fig. 3—Another Type of Admission Pipe Which Is Placed over the Exhaust Pipe and Separated from It by Air Spaces

[1] M.S.A.E.—President and chief engineer, Dorris Motor Car Co., St. Louis.

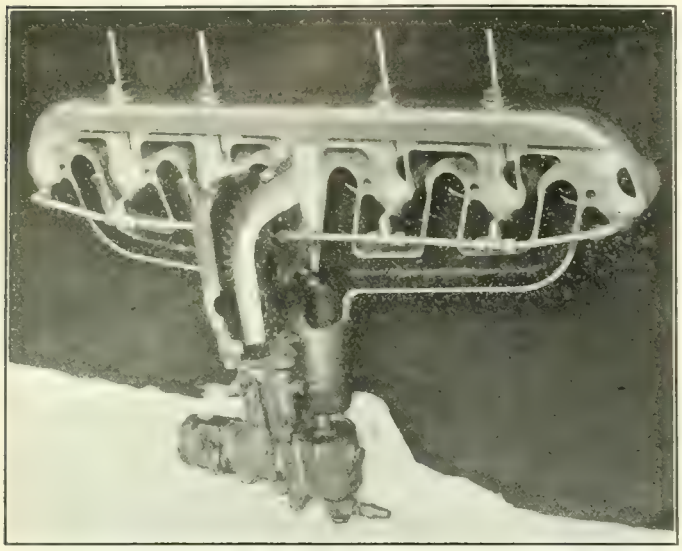


FIG. 4—ANOTHER VIEW OF THE ADMISSION PIPE SHOWN IN FIG. 3 WITH ONE-HALF REMOVED TO SHOW THE PIPE EMPLOYED TO RETURN THE HEAVY FUEL ENDS TO THE CENTER POCKET OR VAPORIZING STILL

them over to the cylinder in a readily mixed fuel for combustion.

TIME FACTOR REQUIRED FOR VAPORIZING

As the average motor-car engine requires approximately 1/25 sec., at a car speed of 30 m.p.h. to vaporize, compress and expand one charge, it is plain that the time required to vaporize the heavy ends is considerably longer than that available at this rate of operation; therefore it becomes very desirable to provide for delayed passage of these heavy ends so as to supply sufficient heat for their thorough vaporization, to use them as a vaporous fuel and to prevent any liquid fuel, or heavy ends, from entering the engine cylinders. The latter has caused disastrous results in crankcase oil dilution and premature wear in the engine bearings.

Fig. 1 represents an admission-pipe of a six-cylinder engine, the two center ports of which being exhaust ports form a hot-spot immediately above the carbureter inlet, so that all heavy ends are thrown against the hot wall between the exhaust and admission pipes. The light ends are passed on to the cylinder as a vaporous fuel and the heavy ends vaporized against this hot-spot. This pipe was satisfactory using the fuel which was obtainable from 1917 to 1919. For experiment, the ends of the manifold were tapped for drains, whereby an inspection could be made of the process of delivery of the fuel to the cylinders. In starting the engine at a temperature of 32 deg. fahr., 2 oz. of liquid fuel was collected in getting the engine warmed up to the operating temperature. The bottles would continue to fill slowly after the engine was warmed up. An inspection of the fuel in the bottles showed a 46-deg. Baumé gravity, while samples taken from the vacuum-tank supplying the carbureter showed 68 deg. Baumé gravity. This test proved conclusively that the fuel yielded freely to an evaporation of the light ends, leaving the heavy ends to trail along the bottom of the admission-pipe to the two end cylinders. From this it was obvious that a better utilization of fuel could be had under improved operating conditions.

Fig. 2 shows a revised manifold, wherein the admission-pipe is cast integrally over the exhaust-pipe, whereby considerable additional heat is applied and better vaporizing of the heavy ends accomplished. In making this pipe a pocket was provided between the two center exhausts, which is the lower pipe shown in the illustration, this pocket being an enlargement of the admission-pipe and set below the point at which the fuel enters the admission-pipe. This pocket collects considerable of the heavy ends on starting. The two center exhaust walls provided heat for vaporization after the engine was thoroughly heated up. Additional pockets were provided below the inlet ports, so that all heavy ends that might be projected over to the engine ports would be collected and their delivery delayed until such time as sufficient heat could be applied to vaporize them. To complete this experiment, bottles were connected to these ports and smaller amounts of the heavy ends were collected in proportion to the starting temperature and the use of the choker-valve in starting. Blind tubes were set into the admission-pipe down to the point of port-opening into the cylinder so that thermometers could be set into the pockets and the temperature of the gas at the point of admission to the cylinder noted. This temperature averaged 235 deg. fahr., which permitted the engine to operate in a very satisfactory manner, with very clean combustion and practically no carbon deposit, but, on account of the decreased volumetric efficiency, the engine lost power.

A third admission-pipe was made as shown in Fig. 3, it being placed over the exhaust-pipe and separated from it by air-spaces so that the admission ports were heated by being cast adjacent to the exhaust-ports, which secured a reduction in heat to the admission-pipe. Fig. 4 illustrates this admission-pipe with one-half removed and four of the thermometers in place. Six were used in the original experiment, but for production reasons the two end bosses have been eliminated. The thermometers show an average temperature, with the changed manifold, of 175 deg. fahr.

By utilizing a vacuum we vaporize a large portion of the light ends of the gasoline and do not heat the air or raise the admission-pipe temperature unduly.

Figs. 2, 3 and 4 show auxiliary heaters of different capacity bolted to the admission-pipe. These heaters are controlled by valves, more or less hot gases passing from the exhaust to them. Fig. 4 shows the admission-port pockets with the piping to return all heavy fuel ends collected to the central pocket or vaporizing still where they are stored until sufficient heat is accumulated to vaporize them.

With this type of manifold it has been possible to eliminate crankcase oil dilution completely and effect a reduction in carbonization. The lubrication efficiency has been improved. An improvement has been effected in acceleration and quick starting and the engine will run at a constant speed with a good torque within 1 min. after starting. A 4000-lb. car has covered 17 miles on a gallon of gasoline in a straight run at 30 m.p.h. In a 1-gal. test using kerosene as fuel a car equipped with this manifold made 17.1 miles. These results prove the efficiency of the equipment in preventing the passage of liquid fuel to the engine cylinders.

Engineering Analysis Applied to Truck Selling

By N. J. Ocksreider[1]

Chicago Truck and Tractor Meeting Paper

WHEN I read, write or think of the automotive industry, I segregate, almost invariably, the progress of this field into three 10-year periods, (*a*) that of experiment, (*b*) development and manufacture and (*c*) marketing. Most of the older people in the industry can recall readily the old one-cylinder type engine, built that way supposedly so that engine trouble could be more "readily located." The second 10-year period showed considerable development in 2, 4, 6, 8 and 12-cylinder engines. We are on the third 10-year period now marketing.

The old hit-and-miss idea of selling a prospective buyer of a motor truck anything he was willing to accept has disappeared. In its place the builder and the distributer have made great strides toward developing the selling of motor trucks on a thorough analysis basis. The builder must of necessity, to make his vehicles stand up, sell to the user the particular size truck that best fits the latter's requirements. In days gone by a truck salesman was too ready to sell a 2-ton truck to meet a particularly flexible requirement and as a result much trouble developed and brought about to a large extent lack of faith on the part of the user. When a truck is properly sold, it invariably gives far better results than a truck of the same size and make that has been improperly sold. The salesman must develop his method of selling along much broader lines. He must be able to observe and apply himself analytically. He must find the true problem as it exists and prescribe the proper remedy. Often an analysis of the customer's problems will show the salesman that the vehicle he sells cannot be used. He must then so inform the buyer and tell him what he should put in operation. The distributer and the builder must encourage this manner of selling through methods of training such as have been used by many of the larger manufacturers of specialties, including adding-machines, cash-registers and loose-leaf accounting systems. The motor-truck problem of today is not one of manufacture. There are questions of detail and refinement which the producer has yet to solve, but we know how to make remarkably efficient transportation machines. The great problem today, which invokes the honest consideration of the builder and the dealer as well as the user, is one of adaptability. What the user must decide is whether motor trucks or horses will best serve his needs, or whether a combination of these will produce the most desirable results.

The builder and the dealer must place themselves in the position of transportation experts, competent to give sound advice on questions arising in the field under discussion. Salesmen must be employed who are capable of analyzing a prospect's requirements and they must be encouraged to advise the prospect to act in his own interest, even at the risk of losing a sale. It is a great credit to the industry that there are cases on record where this attitude has been adopted and practised. It is obvious, of course, that the builder makes trucks to sell. It is precisely for that reason that he should see to it that his trucks are sold only where they can perform work most economically. This policy will inevitably develop "repeat" customers; any other will create enemies. The motor truck in its proper place is one of the greatest assets of modern life. Misplaced it is an economic waste.

Selling by analysis is not at all new. It has been in operation to my personal knowledge for more than 15 years; it is being used by nearly every large progressive industrial institution in America today. Some apply it more intelligently than others, but in a great majority of the cases the sales manager who is at all progressive realizes what the requirements of an analysis are. Charles M. Schwab very ably summed up the subject of selling by analysis in a single paragraph when he said:

> The super-salesman is a man true to the interests of his customer. His supreme purpose is to quicken the imagination of the customer and make him see the true virtue of the goods he is selling. The super-salesman foresees the needs of his customer and provides against those needs in full faith that the event will justify his foresight. He puts his ideals above his profits, in full confidence that profits will surely accrue to fine ideals intelligently executed.

There is nothing especially difficult about selling by analysis. It does not mean that a man must be a technical expert. It requires only a good supply of common sense, mental alertness, a fair amount of imagination and adequate capacity for work.

Market Analysis

In a Packard distributership where market anaylsis has been profitably used, a truck salesman had the following conversation with his manager:

> I am very sorry to be $700 behind in my drawing account. That is a lot of money to pay out and get nothing in return, but I think conditions will change.
>
> It is not the $700 that worries me, but the $6,000.
>
> You haven't paid me $6,000. I am only $700 behind in my drawing account.
>
> That's right. But what worries me most is the $6,000 in gross profit which we have lost due to the fact that you have not sold as many trucks in your territory as was anticipated. We assigned you part of the city with a thorough knowledge of its sales possibilities. We know how many vehicles are operated there now and in what lines of trade. We are further informed regarding the commercial activity in that section. We are not worrying about your drawing account, but about the business you are losing to competitors.

Do you know the potentialities of your territory for the sale of motor trucks in 1921?

How many of each size will you require during 1921, and in what months?

[1]Chief transportation engineer Packard Motor Car Co., Detroit.

What trades in your territory use the majority of motor trucks?

Do you know what share of the business is going to your competitors, and in what trades?

How do you determine quotas for salesmen? Can you prove that your territorial assignments are based on an equitable division of sales possibilities?

Do you know from which trades you can secure the greatest results with the least expenditure of selling energy?

Knowing the Facts About the Market

One of the most valuable assets in a business is the selling organization, and its effectiveness will vary in accordance with the available knowledge concerning the market. To profitably distribute any commodity it is necessary to analyze the market to determine the factors affecting it today and to anticipate future conditions. The whole trend of distribution is away from the old methods of trial and error and toward greater dependence upon scientifically determined facts.

Prosperity depends very largely upon accurate knowledge of the market. If there is a market in your territory for 5000 trucks in 1921, and you have a quota of 500, you must sell 1 in every 10. But if you erroneously anticipate a market for 10,000 and confine your efforts to selling only 1 in 20, the end of the year will probably find you with a warehouse full of unsold trucks. Distribution based on accurate knowledge of a market will reduce sales expense, because it eliminates useless expenditure of selling effort and directs it where it will produce the greatest results. Scientific distribution cuts down footwork and increases headwork. You can continue the old hit-or-miss methods, but are you sure that your competitors will not improve their methods?

Making a Market Analysis and Its Results

Two basic types of market analysis have been successfully applied to date by Packard distributers. The first type depends upon a study of motor-vehicle registration records according to geographical location, trade classification and make of truck. The second type is a personal canvass of a territory to determine all actual owners of motor trucks and to locate all potential prospects. This article will deal with the registration method. Secure an accurate motor-truck registration-service covering your territory. The information usually given is the license number, make, capacity and engine number of the vehicle, together with the name and address of the owner. Transfer the records to a card index. When all the cards are typed they should be filed alphabetically according to the owner's name. In this way all the vehicles belonging to each company will be automatically consolidated, and fleets of trucks will be represented as a whole. The next step is either to rearrange these cards according to the line of business or to make a duplicate set for that purpose. If thought necessary, a third set can be made and arranged according to the make of truck. There is no end to the information obtainable in this manner.

Among the advantages of market analysis may be mentioned:

(1) Knowing the trades active in each territory and estimating their probable requirements, your factory allotment can be accurately determined, thus preventing an excess of unpopular units and a paucity of units in demand
(2) Equitable assignments of territory to salesmen
(3) List of prospects for new trucks according to trades
(4) Prospects for second-hand trucks
(5) Comparative sales value of trades
(6) Active mailing-list according to trades
(7) Strength of competitors according to trades
(8) Where the manufacturer's trucks predominate, the information is especially valuable for sales use
(9) In trades where competitors' trucks predominate, steps can be taken to correct this situation

STANDARDIZATION AS BROUGHT ABOUT BY THE SOCIETY

(*Concluded from page* 34)

these standards and practices are so woven into the conduct of affairs in the industry that many who have not been in intimate association with their creation or who have not seen the lessening of troubles in drawing-room, factory, purchasing department and sales department because they were not familiar with conditions before the advent of the standards, do not realize that any other condition could exist. One of the greatest advantages of standardization is the fact that any shortcoming which develops and is corrected, or any improvement which is made is immediately reflected in the whole industry and is available to all, thus lifting the excellence and serviceability of the product of the industry as a whole. This is, of course, one reason why standardization is not applicable to proprietary or patented articles, and has its greatest value in items of form, dimension and material composition, where individual effort brings about inconsequential differences which are nevertheless differences and as such cost money.

One of the tendencies in modern business which is most notable is that of getting together, getting acquainted with the other fellow and his viewpoint. When this is done, we recognize that if we lock ourselves and our ideas up we will undoubtedly lock out much more than we lock in. I do not think I am stretching the point when I say that to the automotive industry belongs a large share of the credit for this change of view, and I hope you will pardon as harmless pride my further belief that the work of the Society of Automotive Engineers and its Standards Committee has been no small factor in showing the way in our industry.

As chairman of the Standards Committee, I can assure you that the policies which were laid down by the men who sponsored this work in its inception are being followed. We do not confine our consideration of suggestions and criticism to those received from members only, but hold our doors wide-open to any who have worthwhile matters to present.

You who have joined together in this organization and realize the benefits to be obtained from coordinated effort will, I am sure, appreciate the value of this work which the engineers of the industry have done.

Practice and Theory in Clutch Design

By Herbert Chase[1]

Semi-Annual Meeting Paper *Illustrated with* Drawings

THE objects of this paper are to (*a*) set down in convenient form for reference purposes particulars concerning American and British[2] practice in clutch design, (*b*) compare the advantages and disadvantages of various types of clutch and (*c*) give some notes on the theory of design without attempting a comprehensive treatment of the numerous factors involved in this theory. The descriptive portion deals almost entirely with clutches used on passenger cars and trucks, but some of the clutches described are applicable to other automotive uses. The notes on the theory of design apply in general to all automotive clutches. The clutches considered can be divided into the four general classes of cone, single-plate, multiple-disc and shoe or band types.

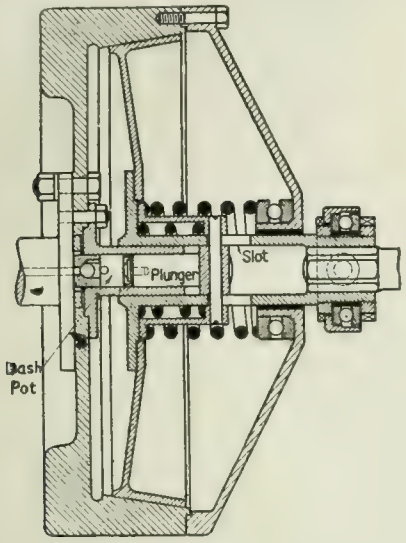


Fig. 1—Cone Clutch with Dashpot

The Cone Type

The cone type was used almost exclusively for many years for both passenger cars and trucks. It still is used very widely by Continental European and British builders, and has a considerable number of advocates in this country. It is simple in construction and can be made light enough to be brought quickly to rest when changing gear, at least in moderate capacities. In certain forms it is not expensive to manufacture and is fairly reliable; but, for a variety of reasons, it has steadily lost ground in this country and is used to-day by less than 8 per cent of car and 6 per cent of truck builders. In England over 60 per cent of car chassis and nearly 80 per cent of truck chassis still have cone clutches. It should be borne in mind that nearly all British builders make their own clutches, and that the average torque transmitted is much lower than it is in this country because British engines are smaller and, in the average case, of rather higher speed than American engines. Preference for the cone type in Europe is ascribed by some to simplicity and lower cost of production when the quantity is small. There are some who say that the cone type is ideal when properly constructed, and one British writer[3] contends that if the same ingenuity had been expended on the cone type as on the plate and disc types the first named would have proved so cheap, simple and satisfactory that other types would be considered expensive luxuries.

The chief failing of the cone type has perhaps been due to the fact that, as frequently constructed, the full pressure of the spring comes into action immediately upon engagement of the friction surface, thus causing the clutch to grab or pick up its load suddenly. To some extent at least this can be avoided by a variety of means. Among the simplest of these is the placing of subsidiary springs under the facing, so that the whole of the facing is not engaged simultaneously. A dashpot, similar to that shown in Fig. 1, also can be used, but this precludes sudden engagement which is sometimes necessary. Another expedient is to arrange two or more springs so that they come progressively into action on the cone during the period of engagement. Practice in respect to the angle of the cone varies widely, from 10 to 16 deg. in British types. The sharper the angle used, the lighter is the spring-pressure required to carry a given load with a given diameter and nature of surface. The clutch is likely to grab when the angle is made too fine, while a fairly wide angle tends to prevent grabbing but requires a heavy spring. The advantages of both are said to be realized in the construction shown in Fig. 2, in which a double cone is employed. The wide-angle surface engages first, while the narrow-angle face coming later into engagement furnishes sufficient friction to carry the full load without slip.

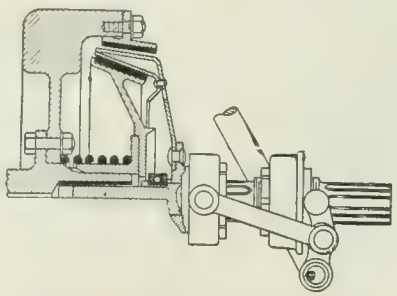


Fig. 2—Double Cone Clutch

Not many years ago all cone-clutch facings were made of leather, which often becomes hard and sometimes

[1]M. S. A. E.—Editorial staff, *Automotive Industries*, New York City.

[2]The data and most of the particulars regarding British clutch practice were furnished by M. W. Bourdon, to whom acknowledgment is hereby made.

[3]See a paper entitled Developments in Transmission by Capt. S. Bramley-Moore which was presented before the Institution of Automobile Engineers and published in The Journal, April, 1921, p. 350.

glazed due to slipping on engagement. The clutch then either fails to carry the load or grabs until the facing is treated with oil. Too much oil lowers the friction co-

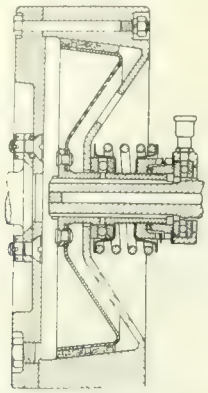


FIG. 3.—THE 10-HP. HUMBER CLUTCH

efficient enough to bring about slipping and fullers' earth must then be applied to prevent slipping. Annoyance of this kind caused prejudice against the cone type and has favored the development of other types. Today, asbestos fabric is employed frequently for cone, as well as for other clutch facings. Cone clutches are sometimes allowed to run in oil, as in the case of the Humber clutch shown in Fig. 3. This keeps the facing material, which is leather in this case, relatively soft and pliable but of course decreases the friction coefficient and, other things being equal, requires the use of a stronger spring.

To facilitate gear-changing, it is desirable to decrease the moment of inertia of the driven member attached to the transmission; hence, its weight and diameter should be kept as low as possible. Some consider American practice superior to the British in this respect and say that gear-changing is easier on the American cars, but this may be due partly to other factors. To minimize

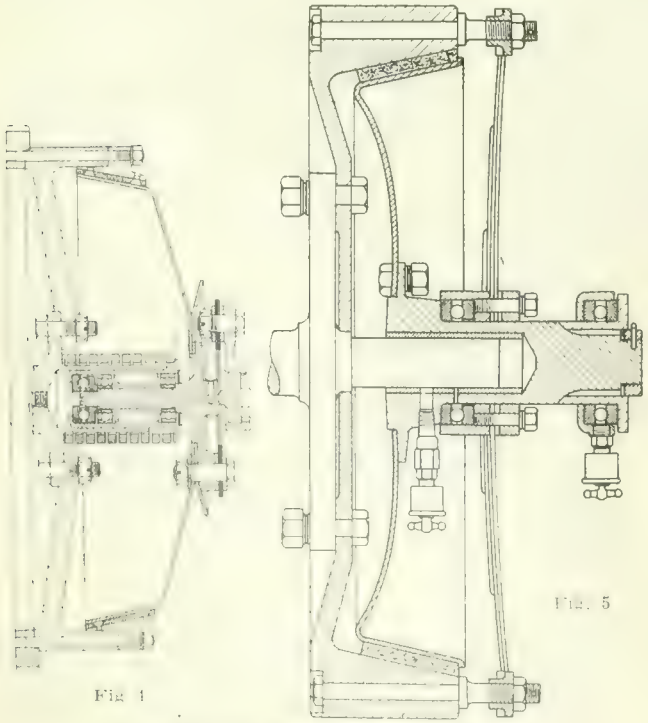


FIG. 4 FIG. 5

FIG. 4.—THE CLEMENT-TALBOT CLUTCH
FIG. 5.—THE THORNYCROFT CLUTCH

weight, either pressed steel or aluminum is employed for cone clutches. In some cases as in the Clement Talbot clutch shown in Fig. 4, the friction facing is attached to the female driving member instead of to the driven member, and the driven member is thus further lightened. This practice is said to have not been universally successful, due to difficulty in attaching the facing satisfactorily. In some cases facings are made and secured in segments, rather than in one piece, when they are carried by the driving member. The builder of the British Phoenix cars has followed the practice for many years of using an aluminum cone running in oil and bearing directly on the cast-iron flywheel. Phoenix cars are of small size, but the practice has apparently been successful, for it is followed even in the latest and largest 18-hp.-model of this maker.

Not all cones are of the conventional form, fitting directly into the flywheel. Some are of the so-called inverted type, such as the Humber, shown in Fig. 3, and are pushed forward toward the flywheel to disengage them. In this case a separate ring is required between the clutch and the flywheel proper. Nothing appears to be gained over the conventional type, unless it be in the compactness realized by placing the spring between the flywheel and the clutch. Nearly all springs used in clutch construction are either helical or volute types under compression. In many cases a single heavy spring centrally located is used, but two or more, equally spaced around the circumference near the periphery of the clutch are often employed. An exception is the Thornycroft clutch illustrated in Fig. 5, which employs two laminated leaf-springs, one on each side of the axis. These are fastened to the flywheel rim at each end by bolts, and make contact at the center with the ball thrust-bearing. The thrust of the engaging spring is usually taken by the flywheel-clutch unit; that is, the two or sometimes the clutch alone are self-contained, and no thrust is transmitted to external members except on disengagement. This is not true, however, in the case of the Daimler car, which has an exterior spring attached to the chassis frame applying pressure to the clutch and flywheel which must be taken up on the crankshaft. This construction is, of course, very much out-of-date.

So far as British practice is concerned, it appears that there is not much to choose between well-made cone and plate types. Their respective merits are so nearly the same that even experienced users accept either type without question. In other words, the type of clutch used is not a selling point in England. This can hardly be said to apply in this country, where perhaps the cone type has not been developed to the same extent as in British practice. The unsatisfactory performance of the cone type in some instances, and other factors, have led to the development of other types here, notably the multiple-disc type, which has advanced further and is more widely used in this country than in Great Britain or Continental Europe.

THE SINGLE-PLATE TYPE

The single-plate type of clutch is used widely in both this country and Europe. When well made and properly adjusted, it is smooth-acting. It is of simple construction and can be made with few parts; consequently it lends itself to economical production in quantity. As compared with the cone and the multiple-disc types, heavier spring-pressure is required to carry the same torque; hence, if the same linkage is used, the pedal-pressure necessary to disengage the clutch is greater,

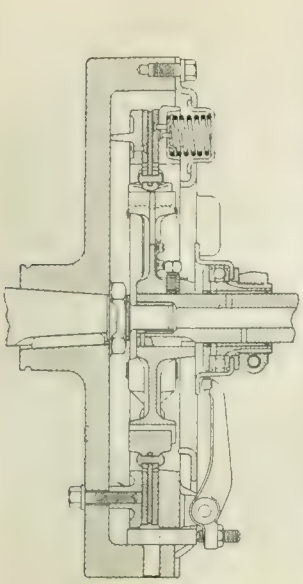


Fig. 6

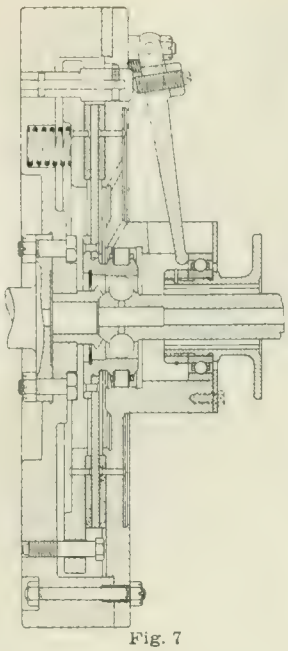


Fig. 7

FIG. 6—THE AUTOCAR CLUTCH
FIG. 7—THE DENNIS 2-TON CLUTCH

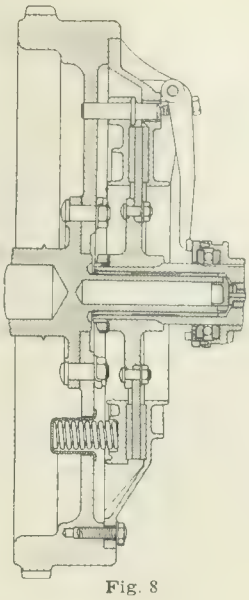


Fig. 8

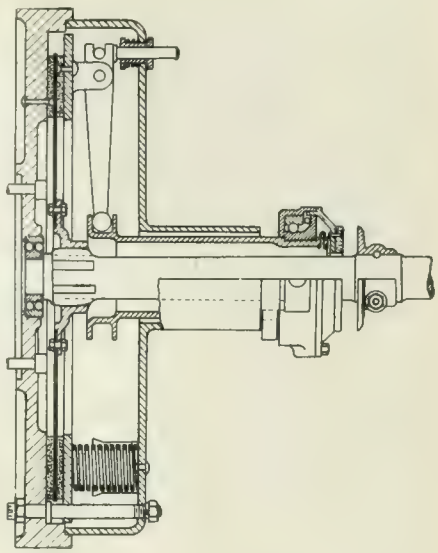


Fig. 9

FIG. 8—THE 40 TO 50-HP. NAPIER CLUTCH
FIG. 9—THE BRISTOL 4-TON CLUTCH

unless a much larger diameter of plate is employed. For this reason multiplying levers are employed in the throw-out mechanism, and many different arrangements of levers are used in plate clutches of different makes. In some cases the levers are attached to and rotate with the driving member, while in others external leverage, aside from that on the pedal lever, is employed.

Figs. 6 to 13 show plate clutches using multiplying throw-out levers. Some of these are employed on trucks and some in passenger-car service. A somewhat different design of lever is employed in all of these eight clutches. In the case of the Autocar, Fig. 6, the Dennis, Fig. 7, and the Napier, Fig. 8, adjusting screws which can be backed off as the facings wear are provided on the levers. The Bristol, Fig. 9, the Halley, Fig. 10, the Mack, Fig. 11, and the Austin, Fig. 12, appear to have no provision for adjustment within the clutch itself. On the Arrol Johnston, Fig. 13, the spring-pressure can be varied by turning the threaded spring-caps, but the levers are non-adjustable. In all of these eight clutches three or more springs, equally spaced in a circle having a radius approximately equal to the mean radius of the friction disc or discs, are employed. These are so-called "direct-acting springs," since their pressure acts

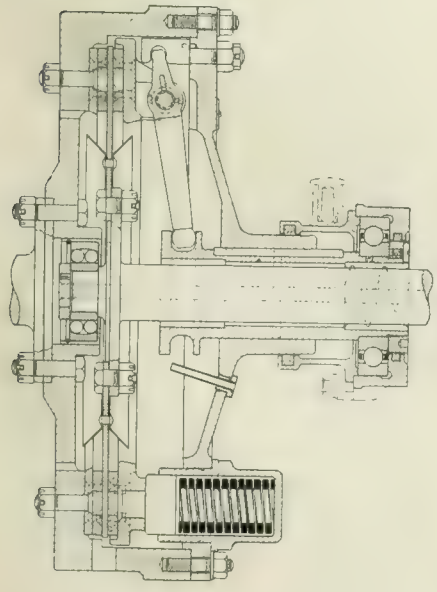


FIG. 10—THE HALLEY 3½-TON CLUTCH

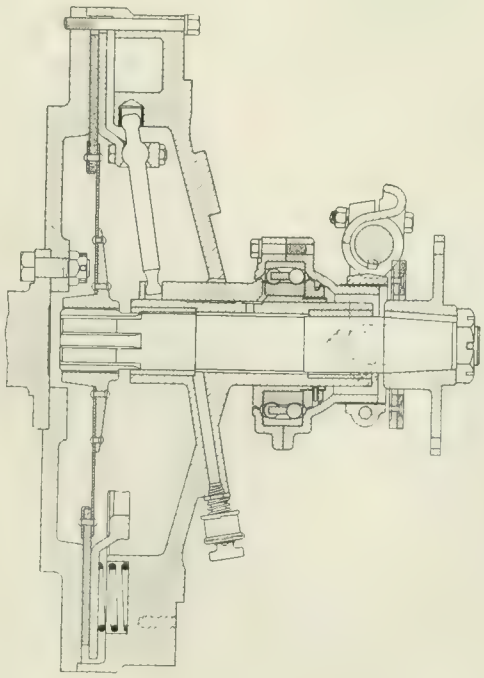


FIG. 11—THE MACK CLUTCH

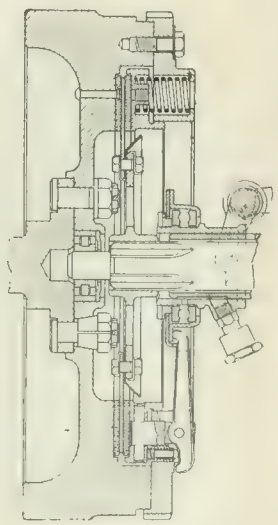


FIG. 12—THE 20-HP. AUSTIN CLUTCH

directly upon the friction surfaces and not through levers, as in the types that will be described later. As the facings wear, the springs become somewhat longer and their pressure decreases correspondingly, but the increase in the length is usually small and, if the spring is properly proportioned, the decreased pressure is still within the capacity factor of safety allowed.

With the single-plate type, the unit pressure on the friction surface usually is high and, since the slip with its consequent abrasive action which takes place during engagement and disengagement occurs as a rule only on two faces, the wear on these surfaces is relatively rapid. This disadvantage of the single-plate type is minimized by making the disc of as large an area, and consequently as large in diameter, as is feasible; but, when the diameter is large, the inertia of the driven member becomes great and gear-changing more difficult. To minimize the weight and inertia of the driven disc, it usually is made fairly thin and the friction surfaces are, as a rule, carried on the driving members. The thin plate is noticeable especially on the Bristol clutch shown in Fig. 9. In some cases, however, so thin a section has been employed that the heat caused by slipping has resulted in warping the plate enough to require its renewal. High temperatures are often reached when, as in traffic driving, slipping occurs frequently. Heat can radiate but slowly from plates so fully enclosed.

The Mack clutch illustrated in Fig. 11 is designed so that the driven friction disc only is clamped between the two driving-members. It is carried by a light steel plate, but is riveted to this plate at points nearer to the center than the bearing surface. This arrangement, no doubt, adds somewhat to the moment of inertia, but it has the advantage of requiring only a single disc of friction material which takes the wear on both sides. Furthermore, as wear occurs, the rivet-heads never bear on the metallic friction-surface as in most other constructions after considerable wear takes place. In this way the useful life of the friction disc is much increased. A somewhat different type of single-plate clutch widely used in this country is shown in Figs. 14 to 16. This type employs a single spring placed co-axially with the clutch itself and arranged so that the pressure of the spring on the facings is multiplied by lever and toggle devices. The advocates of this type claim the advantage of uniform pressure at all points on the friction surface, which, they contend, is not secured when separate direct-acting springs are employed. This advantage is, however, dependent upon having the same size and fit on the various bearing parts involved, as well as on equal wear; hence, there is some question whether a more uniform pressure is obtained in reality than is secured by properly calibrated sets of springs acting directly on the friction faces. One disadvantage resulting from the use of levers to multiply spring-pressure is the fact that the motion of the long end of the lever due to wear on the facings is multiplied in the ratio of the lever arms. If this ratio be 5 to 1, wear of 1/16 in. on the facings means a 5/16-in. extension of the spring. In some designs this amount of motion will involve sufficient reduction of pressure to permit slipping and, since a motion of the throw-out sleeve of about ½ in. is usually allowed, it is necessary with this type to adjust with relative frequency. Hence, clutches of this type are, as a rule, provided with means for quick adjustment.

In the Borg & Beck clutch shown in Fig. 14 adjustment is made by turning the ring on which the toggle-levers are carried, thus causing the inner ends of the toggles to bear sooner on the helical surfaces provided on the thrust ring. The toggle-ring is then locked in place by two cap-screws passing through the cover-plate. In the Hoosier clutch, illustrated in Fig. 15 a similar adjustment is made by turning the threaded adjusting-ring, which is then locked by cap-screws in a manner similar to that used in the Borg & Beck clutch. The release sleeves used in these two clutches are attached to

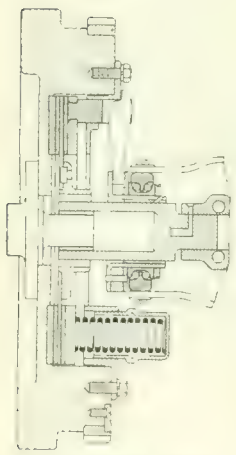


Fig. 13—The Arrol Johnston Clutch

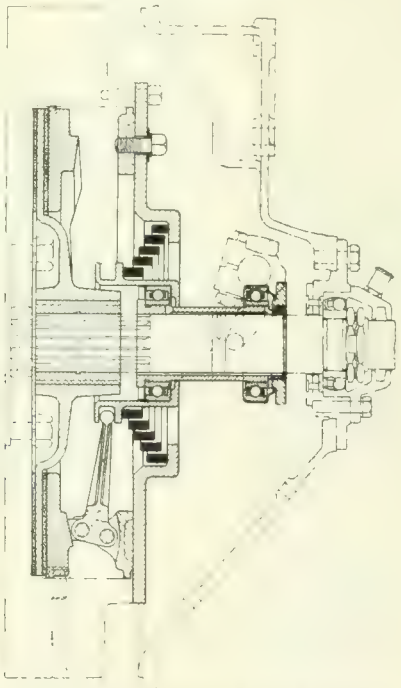


Fig. 14—The Borg & Beck Clutch

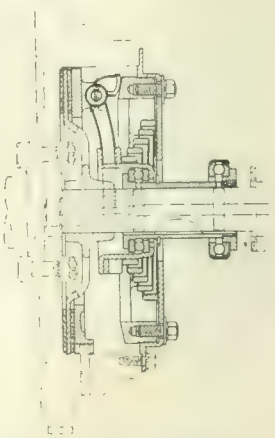


Fig. 15—The Hoosier Clutch

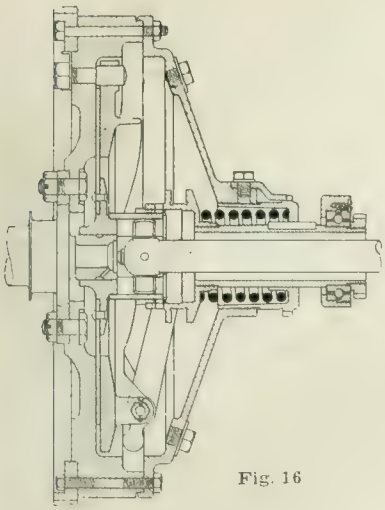


Fig. 16

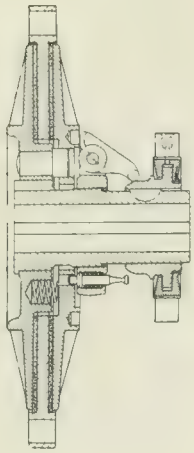


Fig. 17

FIG. 16—THE ROVER CLUTCH
FIG. 17—THE TWIN-DISC CLUTCH

and turn with the driven member, while the collars against which the toggle levers bear at their inner ends turn with the driving member. This necessitates the use of an extra bearing between the two, which is not required in most other constructions. The facings in these two clutches are allowed to float; that is, they are not attached to either the driving or the driven members. Since no rivets are required, the facings can be used without renewal until nearly worn through.

The earlier types of multiple-disc clutch ran in oil and used alternate discs of bronze and steel. With the exception of the Phoenix cars which, as stated above, use aluminum cone-clutches running in oil and bearing on the cast-iron flywheel, few other metal-to-metal clutches are used to-day. One of these is the Rover, shown in Fig. 16, which has a single phosphor-bronze plate running in oil between two cast-iron surfaces. Levers which multiply spring-pressure on the friction surface are employed as in the case of the last two clutches mentioned, but these are not of the toggle type in which a certain wedging action occurs. The use of oil, of course, reduces the coefficient of friction, and this necessitates greater pressure than would be required otherwise. Other disadvantages encountered when disc or plate-type clutches run in oil are cited under the head of multiple-disc clutches. In the case of the Rover clutch the torque transmitted is only that of an engine of 12-hp. rating; hence, it would seem to be possible in a clutch of the proportions shown to work with a large factor of safety, and this is no doubt the case, for the clutch is said to work very well in practice. The Rover clutch is designed for use with a separate transmission; hence, a universal-joint is employed at its center. The disengaging sleeve is keyed to the driving member and therefore rotates with it. Through this sleeve passes the shaft of the universal-joint which, of course, turns with the driven member; but, since this shaft does not touch the sleeve, no bearing is required between them and the thrust of the spring is taken against the casing direct. This makes the extra bearing used in the Borg & Beck and the Hoosier types unnecessary. Spring-pressure can be varied by turning the threaded sleeve, against which it bears, in or out of the conical housing. The bronze driven member apparently wears so little that no other adjustment is required.

A variation of what is essentially a single-disc type of clutch is shown in Fig. 17. This is known as the Twin-Disc clutch and has a pair of driven but only one driving plate, thus reversing the usual single-plate arrangement and materially increasing the weight and inertia of the driven member. No engaging springs are used in the clutch. It is of the locking-toggle type and consequently must be positively engaged and disengaged. For this reason it is not suited to or intended for use on automobiles or trucks, but can be used in some tractor applications. It is adjusted easily by disengaging the spring-retained pin projecting from the threaded toggle carrier-ring, and then turning this ring until the pin falls into another hole on the driven member.

THE MULTIPLE-DISC TYPE

The multiple-disc clutch is regarded by many American engineers as the best of all types for both passenger-car and truck service, as is evidenced by the fact that it is used on nearly all of the more expensive cars produced here. This type of clutch has apparently been developed to a higher degree here than in Europe, while there other types, as previously pointed out, have seen the greater development. Partly for this reason, the multiple-disc type is not used widely either in Great Britain or in Continental Europe, although some car-builders there use it with evident satisfaction. The multiple-disc type of clutch in most forms is more expensive to manufacture than other types, hence, its use has been more general in the higher-priced cars. It is used, however, in many low or moderate-priced cars, in the Ford and the Dodge cars for example, and is not inherently expensive to produce.

The earlier types of multiple-disc clutch were of the metal-to-metal variety and used either all hardened-steel discs or alternate discs of steel and bronze, or steel and copper. Some clutches of this type are still used, such as the Vauxhall, which is shown in Fig. 18. With this construction it is necessary for the clutch to run in oil. This permits a smooth engagement but the use of oil results in more or less trouble, for satisfactory operation of this variety of multiple-disc clutch depends upon having both the correct viscosity and the proper quantity of lubricant. Too much or too viscous lubricant will tend to prevent proper engagement and consequently cause

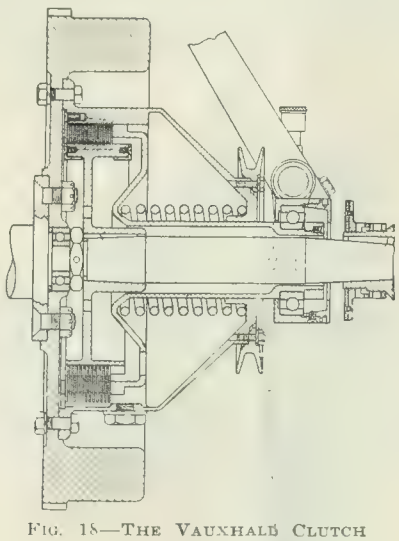


FIG. 18—THE VAUXHALL CLUTCH

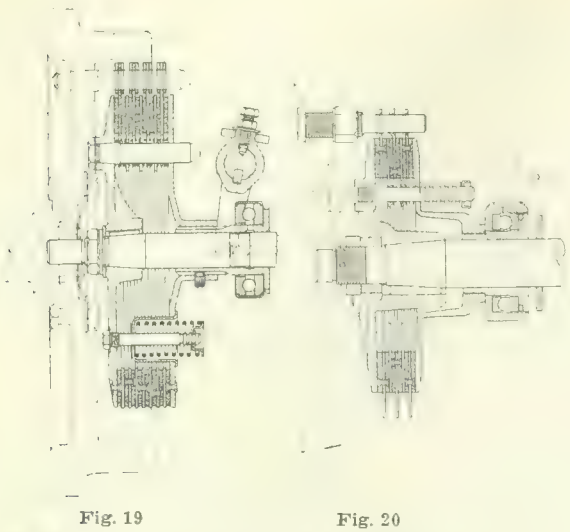


Fig. 19 Fig. 20

FIG. 19—THE HUPMOBILE CLUTCH
FIG. 20—THE DETLAFF CLUTCH

slipping, and will tend also to make adjoining discs adhere when disengagement is required, thus causing the clutch to drag and render gear-changing difficult. Lubricant which is of too low a viscosity or is present in too small a quantity is apt to result in grabbing or cutting of the plates. When oil is used the coefficient of friction is, of course, very much reduced and in consequence many more plates are necessary for a given pressure and diameter to carry a given torque than when dry discs are employed. In consequence, the clutch which runs in oil is, for the same capacity, usually more expensive and heavier than the dry multiple-disc type. For these reasons a great majority of the multiple-disc clutches used to-day have discs of steel, with alternate discs faced with asbestos composition; these discs run dry, and are frequently not enclosed. Clutches of this type prove highly satisfactory in service when well constructed and properly proportioned. They are smooth in engagement, require practically no attention throughout the life of the facings, which last, as a rule, from 20,000 to 50,000 or more miles of car operation, and then are replaced easily. This type of clutch is compact and, since the driven members are light and of small diameter, gear-changing is facilitated. While the number of parts used is greater than in other types, most of these are duplicate stampings, easily and cheaply made; hence, the cost of production need not be high and the clutch is readily made in a self-contained easily removable unit. The large friction surface obtainable in multiple-disc construction makes for long life, and the large number of surfaces permits the use of relatively light spring-pressures and consequent easy action. In some cases fairly heavy springs and a small number of discs are employed without apparent advantage, except perhaps in the matter of cost.

Two distinct classes of multiple-disc clutch are recognized in the American trade; the pin type, in which the drive or torque is taken through pins attached to the driving and driven members, and the gear-tooth or key type, in which gear-teeth, keys or their equivalent take the drive. The Hupmobile clutch shown in Fig. 19 and

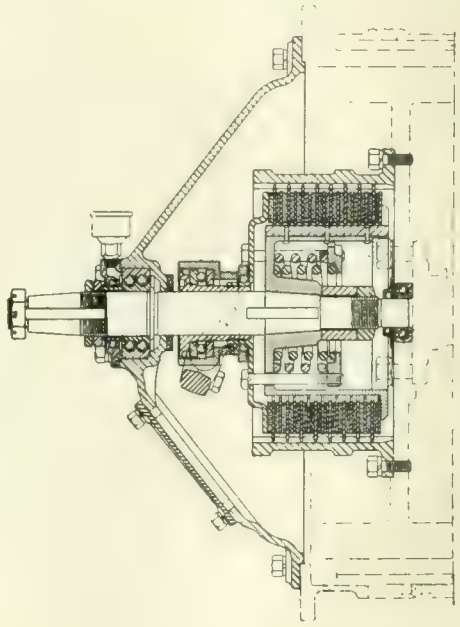


FIG. 23—THE G. M. C. TRUCK CLUTCH

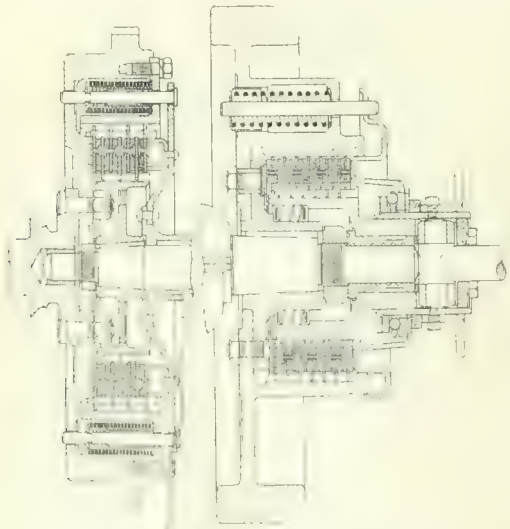


Fig. 21 Fig. 22

FIG. 21—THE CLUTCH USED ON THE PACKARD SINGLE-SIX CAR
FIG. 22—THE CLUTCH WHICH IS USED ON THE REO PASSENGER CAR

the Detlaff clutch illustrated in Fig. 20 are examples of the pin type. The Detlaff company makes also a gear type that is not shown here. It will be noted that the driving discs engage with driving-pins, usually three in number, attached to the flywheel, while the driven discs engage with similar pins carried on the rear driven-member which is, in turn, keyed or splined to the driven shaft connected to the transmission. In the Detlaff clutch the driven pins also carry the engaging springs, but in the Hupmobile design the springs are on separate pins, making a more compact layout, but adding extra parts. The friction facings in one case are riveted to the driving-plates; in the other they are riveted to the driven plates, adding, it would seem, unnecessary weight to the driven unit. In most if not all cases the pin type of construction is less expensive and probably somewhat lighter than the gear or disc type, but it has one rather serious disadvantage as ordinarily constructed.; it is apt to become noisy when wear takes place, because the holes in the discs through which the driving and driven pins pass cannot be made to fit the

pins tightly, owing to the fact that the discs must be free to slide upon the pins and that the discs must be free to expand under heat and consequently must have sufficient clearance to allow this expansion. Since the hole is either somewhat elongated or of larger diameter than the pin, only line-contact between the two is possible without deformation or wear. Since the discs are relatively thin and the pressure due to torque is considerable, wear does take place and chattering frequently results when the clutch is disengaged.

Efforts to minimize wear are frequently made by providing larger bearing surface. This is done in the Detlaff design by punching the holes with a lip turned outward. In the Hupmobile clutch bushings are attached to the discs at the driving-pin holes, but none are provided at the driven pin holes where, of course, the torque and pressure are greater. However, so long as round pins are employed, only line-contact is theoretically possible. In some cases more than three pins are used, thus increasing the number and total area of contact surfaces. The gear or key-type clutch goes another step further in this direction by increasing the number and area of the contact surfaces still more. Examples of the gear type of construction are the Packard, shown in Fig. 21; the Reo, in Fig. 22; G.M.C., in Fig. 23; and the Hilliard, in Fig. 24. The Locomobile clutch shown in Fig. 25 is an example of the key type, while the Merchant & Evans clutch in Fig. 26 is a combination of gear and key construction. The Browne clutch shown in Fig. 27 uses a straight-side tooth on the driving disc, while the driven discs bear on substantial cast lugs. In clutches of these types an external driving-ring, which can be an integral part of the flywheel, and an internal driven drum generally are employed. As a rule, the ring has either internal teeth cut therein or keys usually secured to its internal surface by rivets. The driving-plates are formed to mesh with the ring teeth or keys, with sufficient clearance to slide freely in an axial direction. The drum has teeth or keys cut in or attached to its external surface, and these teeth, meshing with corresponding teeth or recesses in the driven plates, transmit the torque to the driven shaft to which the drum is splined or keyed.

The discs will bear equally on each tooth when well-

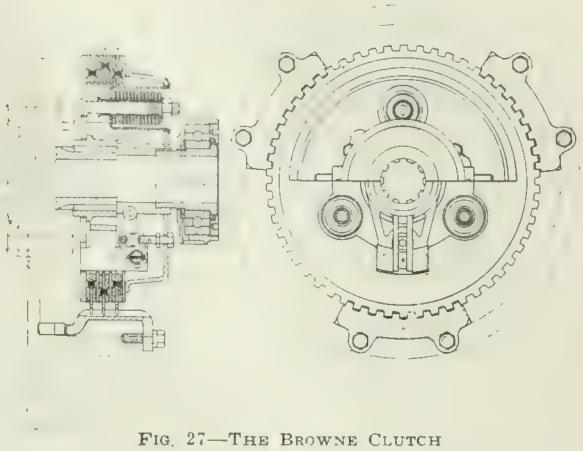


Fig. 27—The Browne Clutch

cut gear-teeth are employed, thus reducing the unit pressure and wear as compared with the pin type. In the key type each key will bear equally over the full area of the notched surface of the disc, when properly made. Since the number of bearing surfaces can be made large, the aggregate surface is considerable and the unit pressure is much decreased relatively. In the Browne clutch shown in Fig. 27 the key-type construction is carried a step further without using keys. The driving plates have straight-side teeth which mesh with similar teeth broached in three separate gear segments attached to a standard S. A. E. flywheel-rim, while driven plates have a large bearing surface on flat-faced lugs cast integrally with the driven spider. The segments are stampings easily and cheaply produced in quantity; their use makes it unnecessary to use an expensive ring-gear with internally-cut teeth. Both the gear and the key types are apt to be less noisy than the pin type, but in general they are more expensive and are therefore used, as a rule, only on the more expensive and higher-powered cars and trucks. They are better suited than the pin type to carrying a large number of plates and usually are able to transmit a higher torque. It will be noted that practice varies considerably in respect to the num-

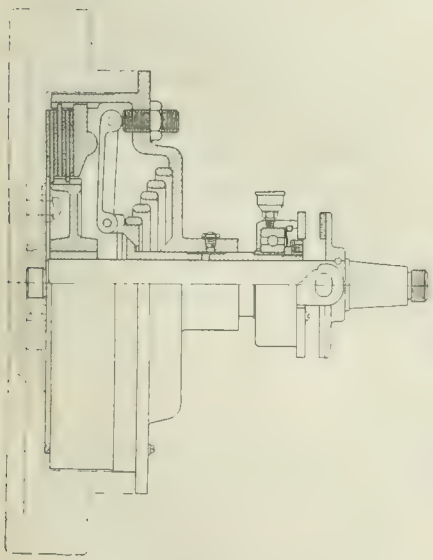


Fig. 24—The Hilliard Clutch

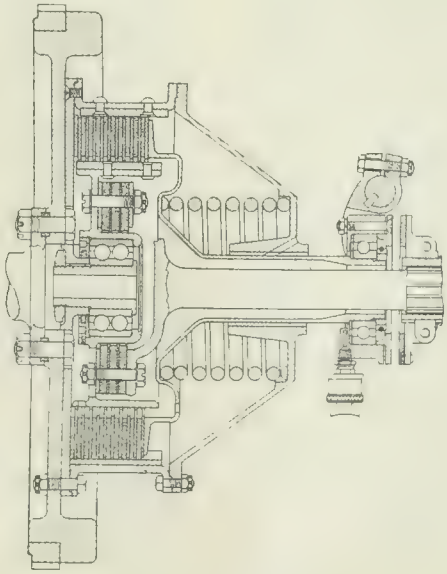


Fig. 25—The Locomobile Clutch

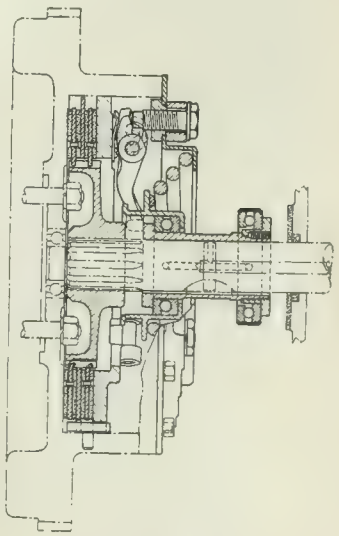


Fig. 26—The Merchant & Evans Clutch

ber of discs employed, the method of applying spring-pressure and the location of the springs.

Since the torque capacity of any plate or disc clutch is directly proportional to the product of the number of surfaces between driving and driven members, the total pressure on the surfaces and the mean radius of the surfaces, it is evident that, for a given torque and mean diameter of clutch, the greater the number of discs is, the less is the pressure required and the less wear there is on the facings; the reverse also is true. The Merchant & Evans Co., which makes the clutch shown in Fig. 26, advocates the use of a small number of discs and therefore employs relatively heavy pressure. To get this without excessive pedal pressure, resort is had to levers that multiply the spring-pressure. In so doing, a construction is employed similar to that used in the Borg & Beck and in the Hoosier plate-designs shown in Figs. 14 and 15. In fact, the clutch shown in Fig. 26 might be termed a two-plate type and is subject to the same disadvantages cited in connection with Figs. 15 and 16, since it requires an extra bearing and relative frequency of adjustment, but it has a larger wearing-surface than the two types with which it is compared.

The other multiple-disc clutches shown employ a large number of discs and, with the exception of the Hilliard clutch which in some cases runs in oil and uses multiplied spring-pressures, have direct-acting springs giving lower total pressures on the friction surface than other types. In the G. M. C. truck clutch shown in Fig. 23, two centrally located springs are employed. In this case the outer end of the clutch shaft is carried in a ball bearing supported by a bell-housing attached to the crankcase. This latter is conventional American practice where a separately mounted amidship transmission is used.

The Locomobile clutch shown in Fig. 25 is unconventional in that the double-row ball pilot-bearing is carried on a spigot extending from the flywheel, whereas this bearing is usually recessed within the flywheel, and in that it incorporates within the clutch a fabric universal-joint. From this joint the driven shaft extends through a tubular extension of the pressure plate, but does not touch the latter. No bell-housing is necessary in this case, although a separate amidship transmission is used. A single central spring is employed. Another rather unconventional construction which incorporates a universal-joint as a part of the clutch unit is that of the Reo clutch shown in Fig. 22, in which the crankshaft is extended well beyond the clutch where a plain pilot-bearing supports a block-type universal at the end of the shaft connecting clutch and transmission. The ball thrust throw-out bearing is placed between the driving pressure-plate and the driven throw-out collar, no other bearing being required between the two. Pressure is applied by three springs carried within the flywheel and equally spaced around the circumference of the pressure-plate. There are six driven plates and only a relatively light spring-pressure should be required.

The clutch used in the latest model of Packard passenger-car is shown in Fig. 21. This is of the more or less conventional design used in connection with unit power-plants. There are but three driven plates; hence, heavier spring-pressure is required than would be necessary with more plates and the same torque. This pressure is supplied by four springs carried between the driven drum and the flywheel. An external multiplying linkage is employed between the clutch and the pedal to decrease the pedal-pressure required to disengage the clutch. A plain pilot-bushing is used within the crankshaft flange. The Browne clutch shown in Fig. 27 is one of the most recent designs of multiple-disc clutch. While it deviates but little from conventional practice it incorporates several refinements in detail which indicate thorough appreciation of the problems involved both in use and in manufacture. For example, multiplying levers are used to decrease the throw-out pressure, which makes for light pedal-pressures without external multiplying linkage, but the springs are direct-acting and proportioned so as to require no adjustment during the life of the facings. The springs are contained within a pressed metal cup and carried on a thin metal tube which is turned over at its ends to prevent the spring from attaining its free length when the spring-bolt nut is removed. The length of the tube is such as to enable the nut to catch a few threads on the bolt before seating on the spring. This greatly facilitates assembling, especially when the clutch is dismantled in a repair-shop for the renewal of facings.

Adjustment is seldom required in the multiple-disc type of clutch with direct-acting springs, and then is made usually by turning up the nuts on the spring-bolts. In the Browne clutch another and very convenient adjustment is provided. The multiplying throw-out levers each carry a threaded bolt with two heads. The outer head projects through a slot in the cover-plate, and is adjusted to bear on the plate. The inner head bears on the inner surface of the cover-plate when the clutch is disengaged. As wear takes place in the friction discs the plate moves inward, leaving the bolt-heads projecting above the surface. When they are seen to project about 3/16 in., they are simply screwed in until they again bear on the plate and the clutch is then again in adjustment. Such adjustment is required only once or twice during the life of the facings. Allowing all the bolt-heads to bear on the plate assures uniform adjustment of the levers.

The Band-and-Shoe Types

Since band-and-shoe types of clutch are little used in automobile and truck applications, no special effort has been made to collect designs of this character, but one of the shoe type known as the Pfeiffer clutch is shown in Fig. 28. This consists of two semi-circular shoes covered with asbestos fabric and arranged to engage the inner surface of the flywheel rim under influence of the spring and toggle mechanism shown. The action is somewhat similar to that of an internal expanding brake. The friction surface is fairly large and, since it is disposed at a rather large radius, the clutch should have high torque-capacity with the multiplying linkage shown, even though the spring used be light. The weight and inertia of the driven member are considerable, however, and therefore gear-changing will not be facilitated, while somewhat frequent adjustment of the toggles would doubtless be necessary on account of the large multiplication of pressure employed. Clutches somewhat similar to external-band brakes have also been used in automotive vehicles, but these are seldom seen to-day and are therefore not described.

Details of Design

All clutches require some type of bearing which will take the thrust imposed by the throw-out mechanism in disengaging. Ball thrust-bearings are frequently employed. These are relatively cheap and give satisfaction when not required to carry radial as well as thrust loads, especially if the construction is such that they run only

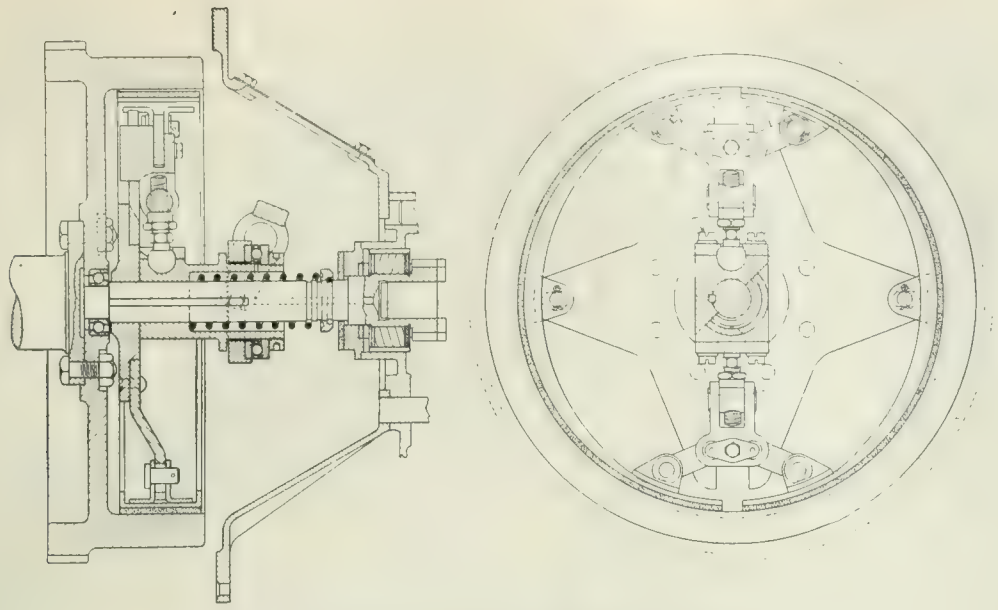


FIG. 28—THE PFEIFFER SHOE-TYPE CLUTCH

when the clutch is disengaged. When radial loads are imposed, either radial or angular-contact ball-bearings are usually employed. These types are somewhat more expensive than the straight-thrust type, but are much better suited to carry radial loads; in fact, the straight-thrust type is seldom recommended, although it is sometimes used when the radial load is light. It is then apt to become noisy and wear eccentric grooves.

When the thrust-bearing is enclosed by a casing which is held against rotation by trunnion-pins bearing upon the throw-out lever, which is a construction that is employed frequently, the bearing runs continually when the clutch is engaged and the engine is turning over. Although the load under these conditions is light, the continual running, frequently at high speed, inevitably causes wear, even though lubrication is facilitated with this construction. A design preferred by many engineers is that in which the bearing does not run continuously. The throw-out levers or ring are arranged to clear the thrust-bearing except during the periods of disengagement, which are relatively very short as compared to the periods of engagement. When so arranged the bearing wears longer if properly lubricated, and even then requires but little lubricant. In fact, it is generally enclosed and packed with light grease which lasts in numerous cases for many months or even years of operation. In unit powerplants whose service is heavy and continuous, provision is sometimes made for lubrication by oil from the transmission by using a hollow clutch-shaft drilled at a point near the bearing. If desired, the pilot bearing can be lubricated in similar fashion, but means to prevent excess oil from reaching the clutch-facings are necessary; otherwise, in the dry type of clutch, slipping will occur. The pilot-bearing, usually carried in a recess in the flywheel or crankshaft flange, is frequently of the radial ball type, but plain or oilless bushings are often used. The pilot-bearing requires little lubrication, but is sometimes lubricated by oil seepage from a porous wicking-plug, one end of which is supplied with oil under pressure in the hollow crankshaft of the engine. The driven members of some clutches, especially those of the cone type, are carried on spigots or extensions of the crankshaft. Usually, they have plain bushes, but ball bearings are used in some cases, as will be seen by reference to the illustrations.

CLUTCH BRAKES

It is customary to provide a clutch brake to reduce the speed of rotation of the driven clutch-members on disengagement and facilitate gear-changing. This is usually in the form of a disc of small diameter arranged to bear on a flange or collar attached to the throw-out sleeve, and in general is made of fiber or asbestos composition. The brake disc is fastened to the gearbox as a rule, in the case of unit powerplants, or to the bell-housing when a separate gearset is employed, but it is sometimes allowed to float on the clutch-shaft between the thrust-bearing and some flat-faced stationary member. The clutch brake is of course more important with clutches having heavy driven-members with considerable inertia than with lighter driven-members, and is not essential in some types, especially the multiple-disc type in which the floating driven-members are light and of small diameter and decelerate rapidly, due perhaps to a degree of dragging which is not, however, sufficient to cause the difficulties which a more positive dragging incurs. In plate and disc clutches it is necessary to provide means whereby the driven members shall be free to float in an axial direction on disengagement, even after some wear takes place. In some designs small relief-springs are arranged to give more positive disengagement, but these are not essential except perhaps in some designs in which the plate or disc runs in oil, which may cause adhesion under certain conditions.

Some details of spring construction have already been discussed, but a few items in this connection remain to be considered. The space allowed for springs and the desirability of compactness in design make it necessary in most cases to use rather short springs. These are often too stiff; that is, for a small change in length, the pressure-change is considerable. The result is that wear on the friction surface decreases the pressure enough to cause slippage. This condition can often be bettered by a change of spring-section and material without variation in overall dimensions or, in other words, by an intelligent design of the spring. In many cases the springs

are mounted so that the decreased pressure occasioned by wear can be compensated by a simple adjustment but, with the direct-acting spring, this adjustment is not necessary if the springs are designed properly and if the capacity of the clutch is correct in relation to maximum engine torque. When several springs are used it is desirable to have them of uniform strength and flexibility, adjusted to give equal pressure to prevent unequal wear and cocking or binding upon release, and with smooth action on engagement, but reasonably satisfactory operation is sometimes obtained in spite of failure to comply closely with these general rules. Some clutch makers prefer a single centrally placed spring, claiming that it gives a more uniform pressure; but this is dependent upon other factors than the spring. This is indicated by the construction used in the Hilliard clutch shown in Fig. 24, wherein a spherical bearing-surface is provided between the pressure-ring carrying the multiplying levers and the throw-out sleeve, with the intention of insuring equal pressure at each fulcrum point on the pressure-plate. Multiple springs are often recessed within the flywheel or placed in pockets of pressed metal in the annular space between the disc facing and the hub. This gives a neat external appearance, reduces windage, facilitates enclosure and minimizes danger of injury when the clutch is turning.

Notes on the Theory of Design

It is not my intention to discuss the theory of clutch design at length, but rather to comment briefly on certain simple basic factors which must be well understood before an intelligent design can be laid down. The maximum torque-capacity of any clutch is given by the equation

$$T = PNrf$$

where

T = the maximum torque capacity in pound-feet
P = the total pressure on the friction surface in pounds
N = the number of engaging surfaces
r = the mean radius of the friction surface in feet
f = the coefficient of friction

Concerning the pressure factor, it is possible theoretically to build a clutch of any desired capacity by simply increasing the pressure on the friction surface, but there are practical limits beyond which it is impracticable to go. A 60-lb. pedal or throw-out pressure is about the maximum permissible, except perhaps in certain truck applications. For comfort in driving, 30 lb. is considered the permissible maximum pressure by some designers, while lighter pressures are desirable in cars intended for ladies' use. It is general practice among American car and transmission manufacturers to use a pedal measuring about 11 in. on the long arm and from 1½ to 2½ in. on the short arm which actuates the clutch. This gives an average leverage of 5.5 to 1. With this ratio and a maximum pedal pressure of 60 lb., the pressure on the short end would be 330 lb., but this pressure should preferably not exceed 165 lb. A compound reduction by links and levers or cams external to the clutch can be employed, but this involves extra parts which are not required otherwise. If direct-acting clutch-springs are to be employed, a pressure of 165 lb. is not sufficient to prevent slippage with the average engine unless the number of friction surfaces or the mean radius of the surface is increased unduly. Two alternatives are employed, so far as the clutch proper is concerned, (*a*) the use of levers to increase the pressure on the friction surface and (*b*) the use of wedging action to increase the pressure on the friction surface. The advantage and disadvantage of each method has been pointed out in the discussion of the various types of construction.

By reference to the illustrations and to Table 1 it will be seen that many clutch designs in which direct-acting springs are employed involve the use of much greater total pressures than 165 or even 330 lb. To decrease the pressure required for disengagement, levers of various forms are incorporated within the clutch. This makes possible the use of a single plate or of fewer discs without involving the chief disadvantage of levers which multiply spring-pressure. From the foregoing it will be seen that there are several methods of varying the factor P in the capacity formula and thus varying directly the clutch capacity, but it should be borne in mind however that, other things being equal, the wear on the friction face is proportional to the unit pressure on the surface; hence it is an advantage to keep the unit pressure low.

An inspection of the capacity formula shows immediately that the capacity of a clutch is directly proportional to the number of friction surfaces engaging. When floating discs are employed between driving and driven members, slip is divided between the two faces; hence, but one face is considered in determining the factor N in the formula of capacity. It is possible to double the capacity of a single-plate clutch by simply adding a second plate and a friction ring. The advantage of the multiple-disc type in this respect is obvious. In this type it is possible to adapt the same clutch to engines of different capacity readily by merely changing the number of plates. The number of plates used will determine, at least to some extent, the ease of engagement or how gradually the full load is picked up upon engagement of the clutch. Increasing the number of plates and decreasing the spring pressure increases the "softness" of engagement and facilitates starting without sudden shock or undue strain on the mechanism.

For practical purposes the mean radius of the friction surface can be taken as equal to one-half the sum of the maximum and minimum radii. The torque transmitted obviously increases as the distance from the center to the point of application of pressure increases, and in direct proportion to this distance; hence, a large clutch diameter is desirable so long as the inertia of the driven member is not too great. The maximum diameter is controlled, however, largely by the size of the flywheel and by the cost of construction, which increases considerably with size. For a given outside diameter of friction surface, the mean radius can be increased by using a narrow facing, especially on plate and disc clutches. Although this decreases the area of surface, practical experience has shown that, within certain limits, a narrower facing wears longer than a wide facing. This apparently is because of the greater uniformity of wear over the entire surface, due no doubt to the fact that the rubbing speed at the outer diameter of a wide annular surface is much greater than at the inner diameter.

Since by definition the coefficient of friction between two surfaces is the ratio obtained by dividing the force required to slide one surface over the other by the pressure on the surface, it is evident that, as applied to clutches, the coefficient is the ratio of the maximum torque each surface can carry to the total pressure on that surface. The coefficient varies greatly with the

TABLE 1—SPECIFICATIONS OF VARIOUS CLUTCHES

Cone Type

Figure Number	Name, Model and Nationality of Car, Truck or Clutch[4]	Number of Cylinders, Bore and Stroke, in.	Maximum Engine Torque, lb. ft.	Dry or in Oil	Facing Material[7]	Maximum Diameter of Facing, in.	Minimum Diameter of Facing, in.	Width of Friction Face, in.	Angle of Cone, deg.	Area of each Friction Face, sq. in.[8]	Number of Wearing Faces of Friction Material	Total Area of Wearing Faces of Friction Material sq. in.[8]	Mean Radius of Friction Face, in.[9]	No. of Driving Members[10]	No. of Driven Members[11]	Number of Springs[12]	Total Spring Pressure, lb.[13]	Total Pressure on Friction Face, lb.[14]	Pressure per Sq. In. of Friction Surface, lb[14]	Torque Capacity of Clutch when New, lb.-ft.[15]	Ratio of Maximum Torque Capacity of Clutch to Maximum Torque of Engine	Pedal Pressure Required to Disengage, lb.[13]	Drive Taken by:[19]	Are Multiplying Levers or Toggle Used:[20]	Means of Adjustment[21]
4	Clement Talbot, 15 Hp. (E)	4-3 1/8 x5 1/8	.....	Dry	Fabric	12 7/8	11.82	2.28	11	88.00	1	88.00	6.17	1	1	1	400	2,100	23.90	.....	.....	....	Univ.	No	None
..	Clement Talbot, 25 Hp. (E)	4-4 x5 1/2	.....	Dry	Fabric	14 9/16	13 3/8	2.28	11	101.00	1	101.00	6.98	1	1	1	500	2,630	26.00	.....	.....	....	Univ.	No	None
..	Commer, 2 Ton (E)	4-4 x4 1/4	....	Dry	Leather	15 1/2	14 1/2	2.00	14	117.70	1	117.70	7 1/2	1	1	1	130	537	4.60	126	.....	24	.....	No	Spring Bolts
.	Commer, 3 1/2-5 Ton (E)	4-4 1/2 x5 1/2	....	Dry	Leather	17 1/8	16 1/8	2 1/2	11	130.60	1	130.60	8 5/16	1	1	1	220	1,160	8.90	220	....	40	Univ.	No	Spring Bolts
..	Dennis, 3-4 Ton (E)	4-4 1/2 x5 5/16	....	Dry	Fabric	17 3/8	15 7/8	3 1/2	12	183.00	1	183.00	8 5/16	1	1	(3)	285	1,380	7.50	208	.....	58	Univ.	No	Spring Bolts
..	Guy, (P) 20 Hp. (E)	8-2 13/16 x4 15/16	.....	Dry	Fabric	15 3/8	14 3/8	2 3/8	12	111.00	1	111.00	7 7/16	1	1	(4)	160	770	6.90	.....	.. ..	35	Univ.	No	Spring Bolts
..	Guy, 2 1/2 Ton (E)	4-4 x5 1/2	....	Dry	Fabric	17 5/16	15 7/8	2 1/2	16	130.60	1	130.60	8.30	1	1	(4)	160	580	4.50	.. ..	.. ..	60	.....	No	Spring Bolts
..	Hartford, (C) (A)	... .	...	Dry	Leather	15 3/4	14 5/8	2 5/8	12 1/2	125.00	1	125.00	7 13/32	1	1	1	225 to 350	1,040 to 1,620	8.30 to 12.90	... ...	.....	...	Univ.	No	Adjustable Spring
3	Humber, 10 Hp. (E)	4-2 9/16 x4 3/4	.....	Oil	Leather	9 7/8	9 7/16	1.77	14	55.50	1	55.50	4.83	1	1	1	280	1,155	21.00	50	.....	30	Keys	No	Spring Nut
..	Humber, 16 Hp. (E)	4-3 1/8 x5 1/2	.....	Oil	Leather	11.82	11 1/4	1.58	14	57.20	1	57.20	5 21/32	1	1	1	245	1,015	17.70	92	.....	30	Univ.	No	.....
..	Maudesley, 3 Ton (E)	4-4 1/2 x5	.....	Dry	Leather	19 7/8	18 3/4	2 9/16	12 1/2	155.90	1	155.00	9 5/32	1	1	1	600	2,775	17.90	.....	.....	25	Univ.	No	None
..	Oakland, (P) (A)	6-2 13/16 x4 3/4	.....	Dry	Leather	12 9/32	....	1 1/2	11	57.00	1	57.90	6.00	1	1	(4)	260	1,370	24.00	137	1.3	15	.....	No	None
..	Sunbeam, 16 Hp. (E)	4-3 1/8 x5 5/16	.....	Dry	Leather	14 1/8	13 5/16	2 3/8	12	101.00	1	191.00	6.80	1	1	(4)	300	1,450	14.40	100	.... .	50	Univ.	No	Spring Bolts
5	Thornycroft, 3 Ton (E)	4-4 1/2 x6	.....	Dry	Fabric	18 7/8	17 5/8	3.00	10	172.20	1	172.20	8 9/16	1	1	2	300	1,730	10.00	375	. .	18	Univ.	No	None
..	Vulcan, 16 Hp. (E)	4-3 1/8 x5 1/8	.. ..	Dry	Fabric	14 1/4	13 3/8	2 3/4	15	121.50	1	121.50	7.03	1	1	(3)	290	1,120	9.30	186	....	40	Univ.	No	Spring Bolts

Single-Plate Type

13	Arrol Johnston (E)	4-3 1/8 x4 3/4	....	Dry	Fabric	8 3/8	4 11/16	1 23/32	..	37.80	4	151.20	3.26	2	1	3	900	900	23.80	100	.....	60	Splines	Yes	Spring Caps
12	Austin, 20 Hp. (E)	4-3 3/4 x5	..	Dry	Fabric	11 7/8	8 1/2	1 11/16	.	54.00	2	108.00	5 3/16	2	1	3	900	900	16.70	...	.. ..	28	Splines	Yes	None
6	Autocar, XXI-F (T) (A)	2-4 3/4 x4 1/2	90	Dry	Molded	12 3/4	9 1/2	1 5/8	.	56.80	2	113.60	5 9/16	2	1	8	800	800	14.10	187.5	2.08	50	Keys and Gear Teeth	Yes	Screws on Levers
.	Autocar, XXVI-Y (T) (A)	4-4 1/4 x5 1/2	185	Dry	Molded	12 3/4	9 1/2	1 5/8	...	56.80	2	113.60	5 9/16	2	1	8	1,440	1,440	25.30	338	1.83	50	Keys and Gear Teeth	Yes	Screws on Levers
.	Borg & Beck, M (C) (A)	... . .	.....	Dry	Fabric	7 3/4	5 1/4	1 1/4	...	25.00	4	100.00	3 1/4	2	1	1	225 to 325	.....	80 to 110	80 to 100	.....	..	Keys and Splines	Yes	
..	Borg & Beck, DX (C) (A)	... .	....	Dry	Fabric	9 5/8	6 1/4	1 1/2	.. .	38.00	4	152.00	4 1/16	2	1	1	225 to 325	.....	50 to 70	120 to 170	.....	....	Keys and Splines	Yes	
..	Borg & Beck, GX (C) (A)	... .	.....	Dry	Fabric	11 3/4	8 1/4	1 11/16	.. .	52.00	4	208.00	4 29/32	2	1	1	225 to 375	.....	35 to 55	150 to 240	.....	....	Keys and Splines	Yes	Rotation of Toggle Mounting Ring
.	Borg & Beck, RGX (C) (A)	... .	.....	Dry	Fabric	11 3/4	7 7/8	2 1/4	....	67.00	4	268.00	4 3/4	2	1	1	225 to 375	.....	25 to 40	150 to 240	.....	....	Keys and Splines	Yes	
14	Borg & Beck, JX (C) (A)	... ..	.....	Dry	Fabric	13 3/4	7 7/8	3	....	101.00	4	404.00	5 3/8	2	1	1	225 to 375	.....	20 to 30	210 to 310	.....	...	Keys and Splines	Yes	

Single-Plate Type (Concluded)

Reference Number	Name, Model and Nationality of Car, Truck or Tractor	Number of Cylinders Bore and Stroke, in.	Maximum Engine Torque, lb.-ft.	Dry or in Oil	Facing Material	Maximum Diameter of Facing, in.	Minimum Diameter of Facing, in.	Width of Friction Face, in.	Angle of Cone, deg.	Area of each Friction Face, sq. in.[7]	Number of Wearing Faces of Friction Material	Total Area of Wearing Faces of Friction Material sq. in.[8]	Mean Radius of Friction Face, in.[9]	No. of Driving Members[10]	No. of Driven Members[11]	Number of Springs[12]	Total Spring Pressure, lb.[13]	Total Pressure on Friction Face, lb.[14]	Pressure per Sq. In. of Friction Surface, lb.[14]	Torque Capacity of Clutch when New, lb.-ft.[15]	Ratio of Maximum Torque (Capacity of Clutch to Maximum Torque of Engine	Pedal Pressure Required to Disengage, lb.[16]	Drive Taken by[17]	Are Multiplying Levers or Toggles Used?[18]	Means of Adjustment[19]
6	Buffalo, 1 Ton (E)	4-41 × 5½		Dry	Molded	7¾	6¼	7/8	...	19.20	6 to 14	115 to 268	3½	3 to 7	4 to 8	3	450	450	23.40	275 to 640	1.6717	...	Teeth and Lugs	Yes	Screw on Toggle Fulcrum
7	Dennis, 2 Ton (E)	4-41 × 5½		Dry	Fabric	13	8 7/16	2 1/2	...	22.60	6 to 18	132 to 396	3 3/32	3 to 9	4 to 10	3	300 to 375	300 to 375	14 to 17	249 to 747	2.5017	....	Gear Teeth	No	Screws on Toggle Levers
10	Hally, 3½ Ton (E)	6-3¾ × 6		Dry	Fabric	15¼	11 3/16	1 31/32	...	26.00	6 or 8	156 to 208	3.6	3 or 4	3 or 5	3	300 to 375	300 to 375	11½ to 14½	225 to 300	2.5017	..	Pins	No	None
	Hoosier, K1 (C) (A)	...		Dry	M or F	7½	5 1/16	1 3/4	...	...	4	...	...	4	5	3	...	...	...	...	...	...	...	Pins and Gear Teeth	No	None
15	Hoosier, K5 (C) (A)	...		Dry	M or F	9¾	6 13/16	1 1/2	...	40.26	4	161.00	4.17	2	1	1	400	...	60.00 Max	200	...	...	Keys and Splines	Yes	Threaded Ring
15	Hoosier, K6 (C) (A)	...		Dry	M or F	11¾	8¼	1 3/4	...	58.90	4	236.00	5.00	2	1	1	400	...	70.00 Max	300	...	...	Keys and Splines	Yes	Threaded Ring
11	Lauth, (C) (A)	...		Dry	Fabric	13¼	9¼	2	...	70.00	4	280.00	5 5/8	2	1	1	...	...	...	...	...	...	Keys and Splines	Yes	None
11	Mack, AC (T) (A)	4-5 × 6	250	Dry	Fabric	19	13	3	...	151.00	2	302.00	8.00	2	1	9	1,035	1,035	6.90	...	...	...	Splines	Yes	Screws on Levers
8	Napier, 40-50 Hp. (E)	...		Dry	...	10 7/16	6 15/16	1 3/4	...	47.80	4	191.20	4 13/32	2	1	(3)	....	....	....	90	...	30	Splines	Yes	Spring Caps
16	Rover, 12 Hp. (E)	4-3½ × 5½		Oil	Bronze	10 5/8	6 3/8	2 1/8	...	57.60	2	115.20	4 3/32	2	1	1	....	....	30.20	90	...	...	Univ.	Yes	Threaded Lever Yoke
17	Twin Disc, A (C) (A)	...		Dry	Either	11½	5½	3	...	80.10	2	160.20	4 1/4	1	2	None	....	....	25 to 35	456	1.837	...	Pins	No	Notched Spring Bolt

Multiple-Disc Type

Reference Number	Name, Model and Nationality of Car, Truck or Tractor	Number of Cylinders Bore and Stroke, in.	Maximum Engine Torque, lb.-ft.	Dry or in Oil	Facing Material	Maximum Diameter of Facing, in.	Minimum Diameter of Facing, in.	Width of Friction Face, in.	Angle of Cone, deg.	Area of each Friction Face, sq. in.[7]	Number of Wearing Faces of Friction Material	Total Area of Wearing Faces of Friction Material sq. in.[8]	Mean Radius of Friction Face, in.[9]	No. of Driving Members[10]	No. of Driven Members[11]	Number of Springs[12]	Total Spring Pressure, lb.[13]	Total Pressure on Friction Face, lb.[14]	Pressure per Sq. In. of Friction Surface, lb.[14]	Torque Capacity of Clutch when New, lb.-ft.[15]	Ratio of Maximum Torque (Capacity of Clutch to Maximum Torque of Engine	Pedal Pressure Required to Disengage, lb.[16]	Drive Taken by[17]	Are Multiplying Levers or Toggles Used?[18]	Means of Adjustment[19]
	Browne, (C) (A)	...		Dry	Molded	7¾	6¼	7/8	...	19.20	6 to 14	115 to 268	3½	3 to 7	4 to 8	3	450	450	23.40	275 to 640	1.6717	...	Teeth and Lugs	Yes	Screws in Levers
	Detlaff, H (C) (A)	...		Dry	M or F	8¾	6½	15/16	...	22.60	6 to 18	132 to 396	3 3/32	3 to 9	4 to 10	3	300 to 375	300 to 375	14 to 17	249 to 747	2.5017	....	Gear Teeth	No	Spring Bolt
20	Detlaff, L & J (C) (A)	...		Dry	M or F	7¾	5¾	1 1/4	...	26.00	6 or 8	156 to 208	3.6	3 or 4	3 or 5	3	300 to 375	300 to 375	11½ to 14½	225 to 300	2.5017	..	Pins	No	None
	Essex, (T) (A)	4-33/8×5		Oil	Cork	....	....	....	...	....	8	....	....	4	5	3	....	....	....	....	....	....	Pins and Gear Teeth	No	....
	Fuller, G(C)L (C) (A)	...		Dry	M or F	8	6	1	...	22.00	14	308.00	3.50	7	8	1	350	350	15.90	196	...	...	Pins	No	None
23	G. M. C., (T) (A)	4-4½×6	203.0	Dry	Molded	8 3/8	6¼	1 1/16	...	14.50	16	232.00	3.66	8	9	2	320	320	22.00	...	...	33	Gear Teeth and Keys	No	None
24	Hilliard, XDA (C) (A)	...		Either	Molded	10¾	6¾	2	...	55.00	4	220.00	4 3/8	3	2	1	380	1,000	34.50	630 or 787[16]	...	...	Gear Teeth	Yes	Screws on Cover-Plate
	Hilliard, S6 (C) (A)	...		Either	Molded	12	8	2	...	63.00	6	378.00	5.00	4	3	1	375	1,875	30.00	709 or 997[16]	...	...	Gear Teeth	Yes	Screws on Cover-Plate
	Hilliard, S8 (C) (A)	...		Either	Molded	12	8	2	...	63.00	8	504.00	5.00	5	4	1	375	1,875	30.00	1,155 or 1,418[16]	...	...	Gear Teeth	Yes	Screws on Cover-Plate
	Hoosier, K19 (C) (A)	...		Either	M or F	7½	5 3/8	7/8	...	17.00	4	68.00	3 1/8	3	2	1	400	....	....	205	....	....	Keys and Splines	Yes	Threaded Ring
	Hoosier, K20 (C) (A)	...		Either	M or F	9	6½	1¼	...	30.00	4	120.00	3 7/8	3	2	1	400	....	....	300	....	....	Keys and Splines	Yes	Threaded Ring
	Hudson, (P) (A)	6-3½×5½		Oil	Cork	....	....	....	...	....	16	....	....	8	8	1	....	....	....	....	....	....	Pins and Gear Teeth	No	....
19	Hupmobile, (P) (A)	4-3½×5½	111.5	Dry	Fabric	9⅝	7⅜	1 1/8	...	30.80	8	246.40	4¼	4	5	6	270	270	8.77	...	...	...	Pins	No	Notched Spring Bolt

Multiple-Disc Type (Concluded)

Figure Number	Name, Model and Nationality of Car, Truck or Clutch[4]	Number of Cylinders Bore and Stroke, in.	Maximum Engine Torque, lb.-ft.	Dry or in Oil	Facing Material[7]	Maximum Diameter of Facing, in.	Minimum Diameter of Facing, in.	Width of Friction Face, in.	Angle of Cone, deg.	Area of each Friction Face, sq. in.[8]	Number of Wearing Faces of Friction Material	Total Area of Wearing Faces of Friction Material sq. in.[8]	Mean Radius of Friction Face, in.[9]	No. of Driving Members[10]	No. of Driven Members[11]	Number of Springs[12]	Total Spring Pressure, lb.[13]	Total Pressure on Friction Face, lb.[14]	Pressure per Sq. In. of Friction Surface, lb.[14]	Torque Capacity of Clutch when New, lb.-ft.[15]	Ratio of Maximum Torque Capacity of Clutch to Maximum Torque of Engine	Pedal Pressure Required to Disengage, lb.[18]	Drive Taken by[19]	Are Multiplying Levers or Toggles Used?[20]	Means of Adjustment[21]
..	Lexington, (P) (A)	6-3 1/4 x4 1/2	....	Dry	....	....	....	....	....	.....	....	.....	....	..	..	....	270	270	.....	.....	.....	....	Gear Teeth	...	.....
25	Locomobile, (P) (A)	6-4 1/2 x5 1/2	283.0	Dry	Molded	10 3/4	8 1/4	1 1/4	...	37.30	10	373.00	4 3/4	5	5	1	285	285	7.64	356	1.28	....	Keys	No	None
.	Mack, AC (T) (A)	4-4 x5	133.0	Dry	Fabric	8 7/16	6 1/4	1 3/32	..	25.10	12	301.20	3.68	6	7	2	320 to 340	320 to 340	12.80 to 13.60	..	....	....	Keys and Gear Teeth	No	Spring Bolts
..	M. & E., 8U (C) (A)	.....	..	Dry	Fabric	7 3/16	5 3/16	1	...	19.59	4	78.00	3 3/32	2	2	1	100	438	24.00	... 230	....	....	Keys and Gear Teeth	Yes	Screws on Cover-Plate
26	M. & E., 10U (C) (A)	.....	..	Dry	Fabric	9 3/16	6 5/16	1 7/16	.	35.00	4	140.00	3 7/8	2	2	1	150	635	19.00	.. 500	....	....	Keys and Gear Teeth	Yes	Screws on Cover-Plate
..	M. & E., 12U (C) (A)	.....	..	Dry	Fabric	11 3/16	7 3/16	2	..	57.70	4	231.00	4 19/32	2	2	1	200	925	16.00	.. 700	....	....	Keys and Gear Teeth	Yes	Screws on Cover-Plate
..	M. & E., 12HD (C) (A)	.....	..	Dry	Fabric	11 3/16	7 3/16	2	..	57.70	6	346.00	4 5/32	3	3	1	250	1,000	19.00	.1,000	....	....	Keys and Gear Teeth	Yes	Screws on Cover-Plate
21	Packard, (P) Single Six (A)	6-3 3/8 x4 1/2	140.0	Dry	Molded	8	6	1	..	22.00	6	132.00	3 1/2	4	3	8	400	400	18.20	.....	.....	20	Gear Teeth	No	Spring Bolts
..	Packard, (P) Twin Six (A)	12-3 x5	238.0	Dry	Molded	8	6	1	....	22.00	12	264.00	3 1/2	6	7	1	400	400	18.20	.....	.....	22	Keys	No	Spring Bolts
..	Packard, 2 Ton (T) (A)	4-4 3/16 x5 1/2	168.0	Dry	Molded	8	6	1	...	22.00	10	220.00	3 1/2	5	6	1	490	490	22.30	.....	.....	25	Keys	No	None
..	Packard, 3-5 Ton (T) (A)	4-5 x5 1/2	210.0[5]	Dry	Molded	8	6	1	..	22.00	14	308.00	3 1/2	7	8	1	490	490	22.30	.....	.....	25	Keys	No	None
22	Reo, (P) (A)	6-3 3/16 x5	238.0[6]	Dry	Fabric	6 5/8	5 1/8	....	..	13.84	13	180.00	2.94	7	6	3	240	240	17.30	.....	.....	....	Gear Teeth	No	None
18	Vauxhall, (P) (E)	4-3 3/4 x5 1/2	....	Oil	Bronze	8 1/2	7 7/16	1 7/32	..	13.34	22	294.00	3.98	11	12	1	90	90	6.70	150	....	17	Gear Teeth	No	None
..	Warner, K19 (C) (A)	.....	..	Dry	.....	....	.....	....	..	20.05	8 to 18	164 to 360	...	4 to 9	5 to 10	3	270 to 405	270 to 405	13.20 to 19.70	140 to 315	.....	....	Gear Teeth	No	Spring Bolts

Shoe Type

..	Ffeiffer, (C) (A)	.....	...	Either	Fabric	13	13	2 1/2	...	49.50	2	99.00	6.50	1	2	1	300	.....	.....	.....	....	....	Pins and Rivets	Yes	Lengthen Toggle

[4] (*A*)—American, (*C*)—Clutch, (*E*)—English, (*P*)—Passenger Car and (*T*)—Truck.
[5] Figures are for 3-ton truck.
[6] Figures are for 5-ton truck.
[7] Bronze indicates bronze plate without facing material, *M*—Molded asbestos composition and *F*—Woven asbestos fabric.
[8] Areas given are computed from the diameter and width without any allowance for rivet holes or depressions for other holding devices.
[9] Figures given are the arithmatical mean radii.
[10] Figures given include the flywheel or members attached rigidly thereto, taken as one member when the friction face bears upon the flywheel or the rigidly connected member.
[11] Figures include only members which transmit torque directly from driving members; a driven member made up of two or more pieces is considered as one member, and driven members such as levers and throw-out sleeves which do not transmit torque *directly* from driving members are not included.
[12] Figures in parentheses are uncertain.
[13] When two figures are given, the clutch maker furnishes springs giving either pressure, or some intermediate pressure.
[14] Figures are presumed to be the maximum pressures when the clutch is new and properly adjusted. When toggles are used to multiply the spring pressure, any slight alteration in the position of the toggles, due to wear or lack of adjustment can make marked variation in total or unit pressure.
[15] In some cases these figures indicate the actual or computed maximum torque capacity, and in others "safe" or "recommended" capacity. In some cases the manufacturer makes clutches of different capacity than the model listed, or will vary the capacity to suit conditions by a variation in the number of discs, friction material or spring pressure.
[16] The first figures are the capacity when arranged to run in oil and the others are the capacity when used dry.
[17] This figure corresponds to the manufacturer's recommendation. Other figures in this column are actual ratios employed presumably with the clutch new or in perfect adjustment.
[18] Figures in this column are the actual pressures used or reported used by the respective manufacturers.
[19] Univ.—Universal-joint. In nearly all clutches the driven members, and in some types the driving members also, must be allowed a certain free axial motion upon release, and some member such as keys, splines, gear teeth or pins which transmit torque and at the same time allow axial motion are therefore provided and these members are listed in this column. The pin or block of the universal-joint frequently performs this function, especially in the case of cone clutches.
[20] Data in this column refer to levers which rotate with and form a part of the clutch, and not to non-rotating throw-out levers external to the clutch.
[21] Data in this column refer to adjusting means within the clutch. External adjusting means are often provided but not referred to here.

nature of the surface and its condition, especially with respect to lubrication. Between smoothn metal surfaces wetted with oil, it is about 0.07. Woven asbestos fabric on smooth steel gives an average coefficient of about 0.3, but this varies considerably with wear, the temperature and the nature of the impregnating material used in the manufacture of the fabric. If the impregnating material contains parafin or other substances which, under the influence of heat, act to some extent as lubricants, the coefficient will decrease as the temperature rises, so that a clutch which performs well when cool sometimes starts suddenly to slip when it has become heated by the slipping that always occurs on engagement. Frequently, repeated engagements such as occur when driving in traffic or careless handling during periods when the clutch is intentionally allowed to slip, sometimes raise the temperature to 500 deg. fahr. or higher; hence, the facing material must be capable of withstanding this temperature and the factor of safety as regards capacity should be sufficient to permit operation even with the reduced coefficient at high temperature. The friction coefficient of woven linings is known to vary through a wide range. One engineer who has made tests with woven facings reports coefficients varying from 0.27 to 0.38. It is considered good practice to use a clutch that has a normal torque capacity when new of 1.6 to 2 times the maximum torque of the engine, although some engineers state that smoother action results when the torque capacity of the clutch is only slightly in excess of that of the engine.

A clutch that will carry a given maximum torque indefinitely when once fully engaged will not always pick up this load without slipping for a relatively long period during which excessive heat is generated. One investigator states that experiment has shown, in the case of multiple-disc clutches at least, that a desirable softness of engagement is secured without undue heating by a clutch that will slip from 50 to 60 revolutions when suddenly assuming full load, and that this slip is obtained when the maximum load carried averages 70 per cent of the total load that the clutch will carry without slip when fully engaged. Within the last two or three years, facings of molded asbestos composition have come to be used widely. They are said to have a friction coefficient of 0.5 and to be more durable than other facing materials. They are of uniform texture, can be made in quantity to close tolerances and do not require a joint secured with wire staples such as is generally employed with the woven fabric. It should be noted that the coefficient of friction is independent of the area of contact surface. For this reason a narrow facing under a given pressure will carry the same torque as a wide facing having the same mean radius, but the unit pressure will of course be greater on the narrower facing. This will tend to cause greater wear, but the wider surface, as pointed out, does not always wear longer because of the greater difference in speed at inner and outer diameters. The ideal condition in this respect is approached most closely by the use of a number of relatively narrow surfaces, thus giving a large total area, a consequent long life and a more gradual picking up of the load, without causing wide differences in speed between the various parts of the contact surface.

In Conclusion

From the foregoing analysis of factors entering into the capacity formula, it will be seen that torque capacity can be made to vary by changes in each of the four factors involved. In other words, the same torque can be obtained by a great number of combinations. The best combination is that which gives the longest life, requires the least attention, is the smoothest in engagement, has the lowest inertia and is the least expensive to manufacture. For passenger-car use at least, the multiple-disc type seems to fill best the greatest number of these conditions, but it is evident from the number of other types used that engineers are far from being agreed on this point. In this connection it is worthy of note that there is wide variation in multiple-disc clutch design. When the price must be kept as low as possible, the number of plates is usually reduced to the minimum and the pressure on the discs is increased; but when cost is secondary to the smoothest action on engagement, the number of plates is increased and the pressure reduced, at the same time prolonging the life of the facings by adding to the total wearing surface.

The data given in Table 1 have been gathered from a variety of sources and no claim is made for their absolute accuracy. Many of the dimension figures were obtained by scaling blueprints and, consequently, they may vary slightly from the actual dimensions used. It will be seen, however, that practice varies so widely in many particulars that the comparisons afforded by the figures given are close enough for practical purposes. It is my hope and belief that the data and drawings collected here will prove useful to engineers who are called upon to design clutches or to make a selection for a given purpose from among the various types of clutch available.

FLIGHTS OF TWO NEW AIRPLANES AT McCOOK FIELD

TWO new airplanes built for the Air Service were given initial flights at McCook Field, Dayton, Ohio, recently. The Loening PW-2, single-seater pursuit airplane was flown by Lieut. J. A. Macready, who reported that it handled very well, was pleasant to fly and possessed excellent visibility. He experienced no difficulties on the flight, which lasted about ½ hr. The airplane, which is equipped with a 300-hp. Wright engine with a four-bladed propeller and carried the full military equipment for the single-seater pursuit airplane developed during the war, is a monoplane with the wings attached to the upper longerons and braced by diagonal struts to the lower longerons of the fuselage.

The G. Elias TA-1 two-seater training airplane was flown by Lieut. George B. Patterson who reported that the airplane balanced perfectly and seemed very light and responsive to the controls. It appears to land very slowly and stops after an unusually short run. The machine is equipped with the 170-hp. Wasp ABC air-cooled radial engine and is the first military airplane that has been flown with the U. S. A. 27 wing-curve, which has given remarkable results in the wind-tunnel tests. With this wing-section only one pair of struts on each side is required for bracing, which greatly simplifies rigging and maintenance in the field. With the exception of the strut arrangement the general design of the airplane follows what is now considered orthodox practice.—Air Service News Letter.

Tractor Pulley Widths and Speeds

IN connection with the Farm Power Meeting of the Society held at Columbus, Ohio, Feb. 10, 1921, a report of the committee that has been invstigating tractor pulley widths and speeds was made by John Mainland, chief engineer of the thresher works of the Advance-Rumely Co., La Porte, Ind.

Committee Report

Our committee held a meeting on Oct. 4, 1920, at Racine, Wis., at which the entire personnel was present. There was a general discussion of the problems under consideration and the following decisions were made.

> The speeds already arrived at by a former committee, 1500, 2600, 3000 and 3500 ft. per min., were approved by the members of this committee.
>
> This committee recommends to designers of pulleys and clutches for new equipment that the minimum diameter be 12 in. and that the pulley width be not less than ½ in. wider than the belt required.
>
> It is the recommendation of the committee that a governor be considered a necessary part of a farm tractor that is used for belt operations and suggests that some means should be provided on tractors for the attachment of a suitable speed-indicating device.

The pulley speeds mentioned above are now published in the S. A. E. Handbook.

A motion was passed that 5, 6, 7, 8 and 9 in. should be a sufficient number of drive-belt widths for all tractor purposes. Chairman Mainland doubted whether a 5-in. width is necessary, but the committee included it, thinking that some of the small tractors might need a belt of this width.

The matter of a standard length for belts was discussed. No recommendation was made but some data were submitted by companies that furnish belts.

On page K40, Vol. 1, S. A. E. Handbook, issued in October, 1920, it is specified that tractors of from 10 to 20 hp. should have a pulley width of 4½ to 6½ in. In Mr. Mainland's opinion, from the standpoint of the tractor a 4 or 6-in. belt-width is perhaps sufficient to transmit the power at the correct belt speed of 3000 ft. per min., but in the field, from a practical standpoint, a tractor with a 4-in. belt is the height of folly so far as threshing is concerned. To put out a tractor with a 4-in. belt is not practical. Mr. Mainland said that he had never seen a separator that could be operated successfully with a 4-in. belt. There are many reasons why it is not practical. If one could set a tractor absolutely in line with a 4-in. pulley, perhaps it would work, but a tractor is operated in the field where the ground is not level and the tractor cannot be made level. For this reason, to operate successfully, it is necessary to have the pulleys more than ½ in. wider than the belt that is to be used.

Mr. Mainland stated at the committee meeting that the pulley on a tractor should be at least 2 in. wider than the belt necessary to transmit the power. Other members of the committee objected to that for various reasons, one of which was that while it is preferable to have the wider pulley there is not room for it in some cases. Mr. Mainland said that tractors run threshing machines more than any other type of machine. He continued: On a threshing machine that we build we make no pulley less than 9 in. wide and we used a 9-in. pulley with a 6-in. belt.

Governors

Several tractors have been put out that have no governors on them. In operating implements perhaps the governor is not necessary, but the tractor, to give its full value, should be able to operate all farm belt machinery. The cylinders of a threshing machine travel at a speed of 6250 ft. per min. on an average. This speed is greater than that recommended for flywheels on steam engines. We all know the old rule that a flywheel should not run at a surface speed of more than 1 mile per min. In operating a separator with a tractor that has no governor, if anything goes wrong and feeding is stopped, the tractor immediately runs away with the separator. It cannot do otherwise. With such a high normal speed, a speed is soon reached that will burst the cylinder of the threshing machine. It is a serious matter when a cylinder of a separator bursts during operation. Almost every State has passed laws in regard to flywheels and precautions have been taken to prevent flywheels from bursting. It is just as necessary to take similar precautions in the case of separator cylinders. If many tractors are marketed without governors, laws will be passed shortly to stop the practice. The Society should take steps to stop the practice before the States pass such laws.

Perhaps there is no subject of which less is known than that of belt speed and pulley widths under the varying conditions of farm work. A machine designed by the Sprague Electric Co. gives very accurate results on belt-driven machinery with regard to the pulleys. So far it has built three of these machines; the earliest one is in the possession of the Goodrich Co.; the second one is at Cornell University; the third and most advanced machine has just been installed at the plant of the Manhattan Rubber Co. I am in close touch with the chief engineer of the Manhattan Rubber Co. and he has told me that all information secured will be available for our committee.

The Discussion

Chairman E. A. Johnston:—If the tractor industry is to have a full measure of success, the tractor must be designed to operate profitably in the hands of the user. Belt slippage or any delay of the tractor outfit on account of trouble with belts is a serious loss.

With reference to the 4-in. pulley mentioned by Mr. Mainland, I believe that that was included because it was felt that for some of the lighter work, such as operating feed-grinders and some of the smaller machines, it would be sufficient. I agree fully with Mr. Mainland that a 4-in. belt is altogether too small to operate a separator economically. With reference to governors, I believe that most tractor designers appreciate fully the need for governors for controlling belt-driven machinery, such as ensilage cutters. There are one or two makes of tractor on which governors are omitted, which is unfortunate for the tractor industry as a whole.

INTERNAL-COMBUSTION ENGINE LUBRICANTS

IN the choice of lubricating oils for the internal-combustion engine the character of the oil used is mainly determined by the high temperatures produced in the cylinders by the combustion of the fuel; it is necessary that no marked decomposition of the oil shall occur to form carbon deposits which will interfere with the smooth and efficient operation of the engine. Minimum carbonization of the oil must therefore take place in the cylinders, and on the other hand the oil must reduce friction as far as possible and remain in effective service for a long time.

Lubricating Oil Tests

The nature of the oil used for lubrication depends on certain features of the engine, such as the method of cooling, engine speed and the clearances of the engine, and accordingly oils of different physical properties varying in viscosity and flash-point are required for the many types of engine. Certain qualities, however, should be possessed by such oils to insure that the engine will continue in serviceable operation without the necessity of frequent overhauling on account of carbon deposits and excessive wear. It is for this reason that tests other than those usually made on oils for the lubrication of machinery operating at ordinary temperatures are necessary to discriminate between various oils intended for the lubrication of internal-combustion engines.

These special laboratory tests have been devised to avoid the necessity of carrying out prolonged and expensive engine tests. Naturally it is of the greatest importance to insure that the results of these laboratory tests do actually correspond with those obtained when the same lubricating oils are tried out in engines; unfortunately, many difficulties arise in carrying out such tests on a sufficiently large scale to determine definitely the relative merits of various oils, since apparently minor factors in the operation of the tests may exert a far greater influence on the results than is produced by changing the lubricating oil. The special laboratory tests used for this purpose are (*a*) Evaporation loss; (*b*) carbonization test; (*c*) carbon content.

The evaporation loss and carbonization test are carried out by heating a weighed quantity of the oil to a high temperature, 300 to 550 deg. fahr., for a definite length of time; from the difference in weight the evaporation loss is readily calculated. The amount of asphalt material or tar in the oil left after evaporation is determined, and this gives the amount of carbonization. It is necessary to carry out this evaporation and carbonization test using special apparatus, and many precautions have to be taken to obtain consistent results. The apparatus and method of Waters for determining carbonization are probably most widely used at the present time. The carbon content is the carbon or coke left on distilling the lubricating oil in the absence of air. Conradson's apparatus is usually employed in this country for the determination of the carbon content of oils. The evaporization loss indicates to a certain extent the consumption of oil that will take place in an engine provided the oil is of suitable viscosity.

Carbonization Test

The carbonization test is valuable because it indicates the decomposition that takes place on the cylinder-head and at other places in the engine where the oil is exposed in the form of a thin film to the high temperature. The carbon content of the oil is not the actual amount of carbon present in the oil, but is the amount of coke or carbon left when the oil is heated in the absence of air. The importance of this test is evident when it is realized that the lubricating oil in the cylinder comes into contact with the combustion flame or very hot surfaces and is immediately vaporized, leaving, however, a small amount of carbon behind. The accompanying table gives a summary of the average temperatures for various parts of internal-combustion engines; of course the temperatures vary to a great extent according to the type of engine and the speed at which it is run.

Part	Temperature, deg. fahr. Gas Engine	Gasoline Engine
Maximum temperature of gas	2,730	3,000-3,350
Piston center of face	750	750
Center of exhaust-valve	750	1,300-1,400
Center of inlet-valve	480	...
Cylinder-head	212-480	400-450
Crankcase	...	100-230

The suction stroke in the four-stroke cycle is the only one in which there is a smaller pressure in the combustion-chamber than in the crankcase, and therefore during this stroke leakage of lubricating oil into the cylinder may take place. The extent of this leakage is dependent on the effectiveness of the piston-rings. It is from this oil, drawn past the piston-rings by the suction, that carbon deposits are formed.

Some of the oil will settle on the piston and cylinder-heads and carbonize more or less rapidly according to the nature of the oil; asphaltic material which forms as the oil decomposes giving carbon. There is, of course, present on the cylinder walls an oil-film which is constantly renewed; this film is probably only slightly affected by the heat of combustion, as the temperature of the cylinder wall is comparatively low, and no appreciable carbonization will take place.

However, the major part of the oil getting into the combustion space is probably present as a fine spray. The heat of explosion may be sufficient to burn completely the smaller droplets, but the larger ones will be only partly burned by the momentary high temperature of the explosion. Thus carbon and asphaltic material are formed from the oil. If the carbon so formed is light in texture, it will be blown out of the exhaust in the same way as the carbon produced from the fuel when too rich a mixture of fuel in air is used; if, however, dense asphaltic material is formed, in the ensuing compression stroke it will tend to adhere to the piston-head and cylinder walls, giving rise to carbon deposits. The carbon deposits in an engine, as is well known, do not consist wholly of carbon, but always contain some asphalt and also metallic particles derived from the water in the engine.

Suction Stroke Most Important of the Cycle

According to the views here presented, the suction stroke is the most important of the whole cycle, from the point of view of lubrication; the leakage of oil occurring during this stroke is the origin of the carbon deposits found in engines and is also responsible for the total consumption of the oil in the engine. As it is upon the oil-spray in the combustion space rather than upon the oil-film on the walls that this carbon formation is mainly dependent, the rapid carbonization of oil, that is, the carbon content, will be a more important factor in testing lubricating oils for internal-combustion engines than the gradual carbonization at lower temperatures. The consumption of oil in the engine is also more dependent on the viscosity of the oil used than upon its fire-test.

In lubricating oils there are present small amounts of compounds of a resinous character, and as a result of experimental work it has been shown that the extent of carbonization at high temperatures and the carbon content depend to a great extent on the amount of these resins present. These compounds decompose more readily than the hydrocarbons in the lubricating oils. At the same time it must be recognized that the hydrocarbons in lubricating oil also decompose, giving resinous compounds when exposed to air at high temperatures.

Thus carbon is formed from a lubricating oil as a result of the rapid vaporization of the oil at high temperatures and of the more gradual decomposition of the oil at lower temperatures. These processes take place simultaneously in the internal-combustion engine, and from the results of engine and laboratory tests it appears that the first process, rapid carbonization, is mainly responsible for the formation of carbon deposits and the engine troubles dependent thereon.—F. H. Garner in *Power*.

Standards Committee Meeting

THE meeting of the Standards Committee was convened at 2 p. m. Tuesday May 24, at the West Baden Springs Hotel, West Baden, Ind., with Chairman B. B. Bachman presiding. After declaring a quorum present, Mr. Bachman reviewed briefly the work of the committee during the four-months' period following the annual meeting, after which he called for reports.

The reports of Divisions submitted to and approved in original or amended form by the Standards Committee, the Council and at a session of the Society at West Baden, are given below for letter ballot of the Members of the Society. The letter-ballot forms will be distributed under separate cover and the ballot counted at the Society offices on Saturday July 23. All ballots to be counted must be received on or before that day.

Ball and Roller Bearings Division Report

(1) *Clutch Release Type Thrust Ball Bearings*

Following a request of the Transmission Division that the Ball and Roller Bearings Division establish a separate standard for clutch releases thrust ball bearings, a Subdivision was appointed which formulated a tentative recommendation.

Clutch Release Type Thrust Ball Bearings

Number	Bore	Width	Ball Diameter
1	1 3/8	5/8	5/16
2	1 1/2	11/16	5/16
3	1 5/8	11/16	5/16
4	1 3/4	3/4	5/16
5	1 7/8	3/4	5/16
6	2	3/4	5/16
7	2 1/8	3/4	5/16
8	2 1/4	13/16	3/8
9	2 3/8	13/16	3/8
10	2 1/2	13/16	3/8
11	2 3/4	13/16	3/8
12	3 1/4	7/8	3/8

All dimensions in inches.

These bores and widths are intended for use with bearings with or without assembling bands.

A meeting was held jointly with the Transmission Division on March 14 at which the returns of the general letter were discussed and the proposed recommendation modified. The final recommendation has been approved as given in the accompanying table.

The recommendation does not include the outside diameters of the bearings because of differences in present practice, but the Subdivision plans to give this matter further consideration.

Data available indicated that approximately 80 per cent of the clutch release type bearings now manufactured are in inch sizes, and that a metric standard would not be acceptable.

THE DISCUSSION

W. R. Strickland:—This proposal is the result of several meetings of the Division and Subdivision, and constitutes a boiling down of about 60 sizes of clutch thrust ball bearing now being used. It was found, in considering the various designs of clutch bearing, that it is impossible to standardize on the outside diameters. The Division thought it would be of advantage to standardize the bores, widths and ball sizes in regular inch dimensions. The report is presented as a step in standardization, with the understanding, of course, that in time corrections or additions may be made.

A. E. Brion:—What has been done in the way of cooperating with the British Society?

Mr. Strickland:—No steps have been taken by the Division to cooperate with the British Society. That is not a function of the Division, I believe. Cooperation with organizations in other countries is had through the Sectional Committee on Ball Bearings of the American Engineering Standards Committee.

R. S. Burnett:—This particular series has not been referred to the Sectional Committee as yet. The present standards for ball bearings have, however, been taken up through the American Engineering Standards Committee with European countries with a view to international standardization.

Mr. Brion:—A large part of the proposal we are considering now is what Mr. Renold, of Hans Renold, Ltd., England, suggested some years ago.

M. C. Horine:—If these are light, medium or heavy series bearings, they are very much under the capacity of what is used in some transmissions. Is not the clutch throw-out bearing at least a medium series bearing, and would it not be well to increase the ball diameters?

Mr. Strickland:—This list is selected from all the bearings being used, and the question of capacity was considered. Even the smaller bearings have the necessary capacity for most of the trucks in service today. Diameters are governed more by the individual design of the clutch than the bearing and the size of the balls increases with the bearing diameters. The question of noise affects that, but I think the question of capacity does not enter.

Ernest Wooler:—Is it not usual to express the bore of bearings in decimals? Should the two halves of the bearing not have different sizes, one to fit tightly on the shaft and the other loosely?

Mr. Strickland:—In the present state of this proposed standardization there would be some question about fixing the sizes. The sizes are nominal, fits being prescribed by the various designs.

Chain Division Report

(2) *Roller-Chain Sprockets*

The first tooth-forms for roller-chain sprockets were designed upon the theory that the tooth action is similar to that of gear teeth, the chain being regarded as analogous to a rack. It was, however, soon found that when chains had been in use a short time the wear at the joints caused an elongation of the pitch of the chain, thus destroying perfect registration with the sprocket teeth which resulted in rough action and rapid wear. The sprocket teeth were then redesigned to provide for the chain elongation by making the tooth-gap somewhat greater than the diameter of the chain roller, but with little or no modification in the contour of the tooth, which was so shaped that the chain roller bore almost squarely against the sprocket tooth, throwing practically the whole load on a single tooth.

Meanwhile, the use of roller chains became more extensive and the demands made on them more exacting. This condition naturally led, both in this country and abroad,

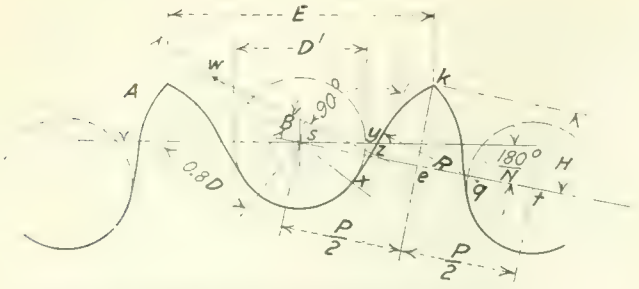


FIG. 1—ROLLER-CHAIN SPROCKET TOOTH-FORM

P — Pitch of chain
D — Nominal roller diameter
N — Number of teeth in sprocket
D' — Diameter of seating curve $= 1.005\ D - 0.003$ in.

$$A = 31° + \frac{90°}{N}$$

$$ws = 0.8\ D$$

$$B = 13° - \frac{18°}{N}$$

xz — A circular arc whose center is at w
zy — A straight line perpendicular to wz

$$xy = 1.3\ D \times \sin\left(25° - \frac{90°}{N}\right)$$

ek — A line perpendicular to st
H — Height of tooth crest above the chord $st = 0.35\ P$
qy — A line parallel to wz with q so located that the circular arc through y will pass through k, thus forming a pointed tooth.

Outside Diameter of Sprocket = Pitch Diameter + $P\left(0.7 - \tan\frac{90°}{N}\right)$ = (approx.) $P.\ D. + P\left(0.7 - \frac{1.592}{N}\right)$

$$E = O.\ D. \times \sin\frac{180°}{N}$$

to a more careful study of the action between chains and sprocket teeth than had theretofore been given to the subject, and it soon became evident that by giving some obliquity to the face of the sprocket tooth, quite different and decidedly better results could be obtained. The action of the forces called into play can be readily analyzed by the graphic method of laying out a parallelogram of forces which will show in true proportion the initial tension on the chain, the resultant thrust on the sprocket tooth (determined by the degree of obliquity selected) and a balancing force passed on to the ensuing links of the chain where this action is repeated in a lessening amount.

By this method the load on a chain can be distributed over several teeth of the sprocket and at the same time, by extending the oblique portion of the sprocket tooth a suitable distance, it is made possible for a chain of elongated pitch to slide outward on this oblique face until it finds a pitch-line on the sprocket coinciding with the lengthened pitch of the chain. These general findings were freely exchanged among the chain manufacturers and one of the English companies published a brochure on the subject. During the war more pressing matters prevented an interchange of opinion on this subject, but nevertheless most of the sprocket manufacturers evolved tooth-forms along these lines.

It is now proposed to effect an agreement upon one standard form that shall supersede the various individual designs and the formula now presented by the Chain Division for adoption as an extension of the present S.A.E. Standard for Roller Chains, page E3, Vol. I, S.A.E. HANDBOOK, is a composite of the best features of the various tooth shapes that have been tried out and pronounced satisfactory.

THE DISCUSSION

MR. HORINE:—This new tooth-form is a proposal to standardize something still in the experimental stage. So far as I know, no trucks have been run for, say, 10,000 miles with this form of chain sprocket. Our company, a

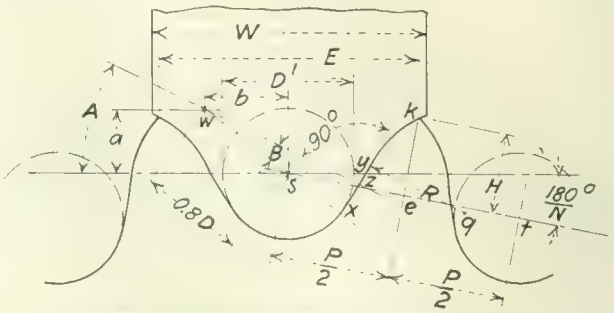


FIG. 2—ROLLER-CHAIN SPROCKET CUTTERS

Cutters shall be designed for 6, 7-8, 9-11, 12-17, 18-34, 35 teeth and over.

The number of teeth on which each cutter shall be based is, $M = \frac{2\ N\ n}{N + n}$, where "$N$" and "$n$" are the maximum and minimum number of teeth to be cut by any given cutter. A sprocket having N teeth will thus have a pressure angle which departs the same amount from the desired pressure angle as one having n teeth.

The values of M for the various cutters are respectively, 6, 7.47, 9.90, 14.07, 23.54 and 65.42 teeth.

Cutter numbers shall be respectively, 6, 7½, 10, 14, 24 and 65.

$D' = 1.005\ D + 0.003$ in.

$$A = 31° - \frac{90°}{M}$$

$$ws = 0.8\ D$$

$$B = 13° - \frac{18°}{M}$$

xz is a circular arc with w as the center
zy is a straight line perpendicular to wz

$$xy = 1.3\ D \sin\left(25° - \frac{90}{N}\right)$$

$sc = \frac{1}{2}\ P$
$ek = H = 0.35\ P$
yq is a line parallel to wz
q = is so located that the arc yk, struck from q as a center, will pass through k

The radius R may be determined graphically.

Where the same roller diameter is used on chains of two different pitches (as ⅝-in. roller, 1-in. pitch; and ⅝-in. roller, 1¼-in. pitch) cutters No. 6 and 7½ shall be designed for the longer pitch, and may be used for cutting sprockets of the shorter pitch. Cutters No. 10, 14, 24 and 65 shall be designed for the shorter pitch and may be used to cut sprockets of the longer pitch.

W = width of cutter $= 1.02 \times O.\ D. \times \sin\frac{180°}{n}$, to the next higher 32nd inch; where $O.\ D.$ equals the outside diameter of the sprocket with the larger pitch and the lowest number of teeth to be cut with the cutter.

Note: The specifications to the cutter maker may be simplified if w and z are located as follows:

$$a = 0.8 \times D \times \sin\left(31° + \frac{90°}{M}\right)$$

$$b = 0.8 \times D \times \cos\left(31° + \frac{90}{M}\right)$$

$$xz = 2.6 \times D \times \sin\left(6\tfrac{1}{2}° - \frac{9}{M}\right)$$

builder of chain-drive trucks, has not had an opportunity to try out this sprocket. While we do not doubt that it contains great promise, I believe that it is not proper to standardize on a tooth which is still experimental and hypothetical. I think we should let this matter go over for a while until we shall have had an opportunity to try the form out.

H. S. PIERCE:—I would like to say something that will probably give a little clearer view on the matter. The form of cutter that is now in most general use was probably designed by the cutter manufacturers who are more accustomed to working on gears. It is a fact that the chain manufacturers themselves in cutting the wheels have not adhered to that general form of cutter which has been principally supplied by the cutter manufacturers. They learned in the very early days that it was necessary to modify it to get the best results.

We have used since about 1908 cutters and tooth-forms which very closely approximate this present one. One of the elements that led up to this standardization was the fact that the form which is in most general use by others than the chain manufacturers themselves was recognized by them as being entirely unsatisfactory. It is true that this tooth-form has slight modifications from any which is in very general use, but the principles involved have all been thoroughly tried out and the compromises that have been made to have a standard are in no case large enough to influence the result. The proposal is not experimental or indefinite. I am not familiar with the particular type of tooth-form that the company which Mr. Horine represents has been using, but this form has been in very general use for a number of years, and we are trying to put it on a firmer foundation.

CHAIRMAN B. B. BACHMAN:—As I understand it, this tooth-form would not change the design of the chains, that is, the chains as they are being made today would be applicable to the sprockets that Mr. Horine is using as well as to those made by the cutters that we are contemplating adopting.

W. F. COLE:—A standard chain will run on any tooth-form which fits that chain. The question has been asked whether the same chain would run on the old sprocket tooth-form and this new sprocket tooth-form. The answer is yes.

In connection with the remark that this new tooth-form has not been tried out on any truck chain, I can report that the chain and sprocket company which I represent has supplied many sprockets cut in accordance with the principle embodied in this proposal, and that they have been used on trucks which have made thousands and thousands of miles. It works out exceedingly well. I am very sure that the same statement can be made by the other chain and sprocket manufacturers.

MR. BRION:—Mr. Renold suggested this tooth-form in 1913; so it must have been used in England for some time.

MR. PIERCE:—There is one element in standardizing the roller-chain tooth-form that is not of the same character as standardizing other things, in that we do not break interchangeability. The proposal is offered as an improved engineering practice. Any properly designed chain that will run on the old tooth-form will run on this new tooth-form, but it will not run as well on the old one.

(3) *Roller Chains*

The Chain Division's recommendation that the present S.A.E. Standard for Roller Chains, page E3, Vol. I, S.A.E. HANDBOOK, be extended to specify chain numbers in accordance with the following numbering system, was approved.

> The left-hand figures shall denote the number of one-eighth inches in the pitch.
>
> The final figure shall denote the roller diameter as follows: "0", the heavy series roller diameter; "1", the medium series roller diameter; and "2", the light series roller diameter.
>
> The letters "W" or "N" shall denote whether the chains are of the wide or the narrow series.

Thus in Chain No. 160W, 16 indicates that the pitch is 2 in., "0" that it is heavy series roller diameter, and "W" that the chain is of the wide series.

The proper numbers for the present S. A. E. Standard chains of the heavy series are given in the accompanying table.

PROPOSED NUMBERS FOR S. A. E. STANDARD HEAVY SERIES ROLLER CHAINS

Chain Number	Pitch	Roller Diameter	Chain Width
30W	3/8	0.2500	0.2500
40W	1/2	0.3125	0.3125
50W	5/8	0.4000	0.3750
60W	3/4	0.4690	0.5000
80W	1	0.6250	0.6250
100W	1 1/4	0.7500	0.7500
120W	1 1/2	0.8750	1.0000
140W	1 3/4	1.0000	1.1250
160W	2	1.1250	1.2500
200W	2 1/2	1.5500	1.5625
240W	3	1.9000	1.8750
320W	4	2.5000	2.5000
400W	5	3.0000	3.0000

All dimensions in inches.

ELECTRICAL EQUIPMENT DIVISION REPORT

(4) *Insulated Cable*

The Electrical Equipment Division's recommendation that the present S.A.E. Standard for Insulated Cable, page B33, Vol. I, S.A.E. HANDBOOK, be revised to conform to the accompanying specifications for insulated cable, was approved. Although the proposal does not as yet include electrical tests, it is desired by the cable manufacturers that the manufacturing specifications be adopted and published without delay so far as they have been completed.

The electrical tests for high-tension ignition cable will be included in the standard at a later date, as no entirely satisfactory tests have yet been developed. The electrical tests included in the present standard, although used considerably in general power-cable testing, are not considered satisfactory for automotive high-tension ignition cable.

The proposed revision is submitted as a practical and satisfactory specification founded on the best commercial experience. It embodies many points in common with Government specifications which have been generally approved and will be used by manufacturers in producing high-grade insulated cable.

INSULATED CABLE

I. General Specifications

Conductors.—Conductors shall be bunched or stranded as specified in each section and shall be of annealed copper wire in accordance with Specification No. B3-15 of the American Society for Testing Materials. All wires shall be thoroughly tinned and must withstand the tinning test as specified in Section II Tests. All tests of copper conductors shall be made before stranding or insulating.

Cotton Separators.—Material for separators, where specified, shall be of good grade cotton and shall be closely and tightly applied.

Rubber Insulation.—Rubber insulations shall be homogeneous in character, properly vulcanized, and placed concentrically about the conductors.

Rubber insulations shall adhere closely to, but shall strip readily from, the conductors, leaving them reasonably clean.

Rubber insulations used on cables covered by these specifications shall contain not less than 20 per cent (by weight) of good grade Hevea rubber which has not been previously used.

Varnished Cambric Tape.—Varnished cambric tape shall be made from a good grade cotton fibre treated with multiple coats of insulating varnish. The instantaneous puncture voltage shall be not less than 750 volts per mil of thickness tested in accordance with the standards of the American Institute of Electrical Engineers.

Varnished cambric tape shall be not less than 0.005 in, nor more than 0.013 in. thick.

Braids.—Braids shall consist of closely woven cotton yarn, and shall not be less than 1/64 in. thick. Braids shall be impregnated with at least two coats of properly dried, heat, oil and water resisting insulating varnish or impregnated with black weather-proof compound which has an even and smooth finish. Adjacent layers of cable, when wound on the reel, shall not stick to one another at any temperature under 105 deg. fahr. (40 deg. cent.).

Armor.—Armor shall be of either galvanized or sherardized soft steel, soft brass, aluminum or copper and applied in a close helix. Successive turns shall not overlap. Armor dimensions shall be as given in Table 1.

Armor shall be solid "D" shaped, unless otherwise specified by the purchaser.

The large armor is recommended for use on all cables exceeding ½-in. diameter underneath the armor.

TABLE 1—ARMOR THICKNESS AND WIDTH DIMENSIONS

Armor	Thickness, In.			Width, In.		
	Min.	Nom.	Max.	Min.	Nom.	Max.
Small	0.014	0.017	0.020	0.045	0.050	0.055
Large	0.017	0.020	0.023	0.095	0.100	0.105

II. Tests

Tinning Test.—For this test, samples of the bare wire before being stranded or insulated shall be properly selected to secure an average grade of tinning The wires shall be thoroughly cleansed by means of ether, benzine, gasoline, naphtha, caustic alkali solution, alcohol, or hot water and soap, whichever may be found necessary to thoroughly clean the wires.

The wires shall then be rinsed in clear water and wiped dry with a soft cotton cloth. The wires shall then be immersed for 1 min. in a solution of hydrochloric acid having a specific gravity of 1.088 at 70 deg. fahr. (21 deg. cent.), and then rinsed in clear water and wiped dry as above specified. The wires shall then be immersed for 30 sec. in a solution of sodium polysulphide which contains an excess of sulphur and which has sufficient strength to thoroughly blacken a piece of clean untinned copper wire in 5 sec.

The complete cycle of operations shall then be repeated, commencing with the immersion in hydrochloric acid and ending with the immersion in the sodium polysulphide solution.

Tests of tinning shall be made on not less than 10 sets of samples of reasonable length. All wires shall withstand one immersion in the hydrochloric acid without blackening in the sodium polysulphide solution, and 75 per cent of the wires shall withstand three immersions in the hydrochloric acid without blackening in the sodium polysulphide solution. All tests shall be conducted with the solutions at a temperature of 70 deg. fahr.

Physical Tests.—A test-specimen of rubber insulation, which has not previously been handled, not less than 6 in. long shall have marks placed upon it 2 in. apart. The sample shall then be stretched at the rate of 12 in. per min. until these marks are 6 in. apart, and then immediately released. Thirty seconds after being released the distance between the marks shall not exceed 2½ in. The test-specimen shall then be stretched until the marks are 7 in. apart before it is ruptured.

The ultimate tensile strength of rubber insulation shall not be less than 600 lb. per sq. in. The tensile strength shall be calculated upon the original cross-section of the test-specimen before stretching.

Physical tests shall be made at a temperature of not less than 50 deg. fahr. (10 deg. cent.), nor more than 90 deg. fahr. (32 deg. cent.).

For the purpose of these tests, care must be used in cutting to obtain samples of uniform cross-section and no manufacturer shall be responsible for results obtained from samples imperfectly cut.

The above physical tests shall not apply to wires or cables having a wall thickness of less than 0.045 in. For wires and cables having a wall thickness of less than 0.045 in. the initial and ultimate stretch shall be 5 and 6 in. respectively, and the tensile strength not less than 500 lb. per sq. in.

Miscellaneous Tests.—The following tests apply to high-tension (secondary) ignition cables only.

Oil Test for Braided Cables.—A sample of cable shall be immersed in a mixture of equal parts of machine oil and gasoline for a period of 24 hr. without allowing the ends of the sample to become submerged. After this immersion the impregnating varnish should not show signs of softening or absorption, and when the braids have been peeled off, it should be shown that no oil has penetrated to the rubber insulation.

III. Specifications for High-Tension (Secondary) Ignition Cables

Conductors shall be stranded and covered with rubber insulation.

High-tension (secondary) ignition cables shall be

TABLE 2—HIGH-TENSION (SECONDARY) IGNITION CABLE SIZES

Nominal Size		Number of Wires in Strand	Nominal Size of Wires in Strand, A.w.g.	Maximum Outside Diameter, In.	Minimum Outside Diameter, In.	Minimum Thickness of Rubber Wall, In. (Plain Rubber Covered)	Minimum Thickness of Rubber Wall, In. (Single Braid)	Minimum Thickness of Rubber Wall, In. (Double Braid)
Mm	In.							
7	0.2756	12 19	26 (0.0159) 27 (0.0142)	0.285	0.265	0.097	0.081	0.066
9	0.354	19 19	27 (0.0142) (0.0147)	0.364	0.344	0.135	0.119	0.104

The 7-mm. size is recommended for all high-tension cable.

plain rubber covered, single braided, rubber face taped and single braided or double braided. Weatherproof braid shall not be used on this type of cable.

High-tension (secondary) ignition cable sizes shall be as shown in Table 2.

IV. Specifications for Low-Tension (Primary) Ignition Cables

Conductors shall be bunched or stranded and covered with rubber insulation.

Low-tension (primary) ignition cable shall be plain rubber covered, single braided, rubber face taped and single braided, or double braided.

Low-tension (primary) ignition cable sizes shall be as shown in Table 3.

TABLE 3—LOW-TENSION IGNITION CABLE SIZES

Nominal Size	Number of Wires in Strand	Nominal Size of Wires in Strand		Maximum Outside Diameter, In.	Minimum Outside Diameter, In.
		A.w.g.	In.		
5 mm. (0.197 in.)	12	26	0.0159	0.207	0.187
	19	27	0.0142		

V. Specifications for Rubber Covered Lighting and Starting Cables

Conductors of cables Nos. 16 to 10 A.w.g. inclusive shall be either bunched or stranded as desired. Stranded construction is recommended for flexibility. Conductors of cables No. 8 and larger shall be stranded and may be either concentric or rope lay.

Conductors shall be covered with rubber insulation.

Note: Lighting and starting cables shall be single braided, rubber face taped and single braided, or double braided.

Lighting and starting cable sizes shall be as shown in Table 4.

TABLE 4—STRANDING AND DIMENSIONS OF LIGHTING AND STARTING CABLE

Nominal Size, A.w.g.	Number of Wires in Strand	Nominal Size of Wires in Strand		Circular Mils		Continuous Carrying Capacity, Amp.	Maximum Outside Diameter, In.	Minimum Thickness of Rubber Wall, In.
		A.w.g.	In.	Nominal	Actual			
	12	27	0.0142		2,418			
16	16	28	0.0126	2,583	2,557	6	0.200	0.022
	19	29	0.0112		2,407			
	19	27	0.0142		3,829			
14	26	28	0.0126	4,107	4,155	15	0.223	0.027
	19	25	0.0179		6,088			
12	26	26	0.0159	6,530	6,607	20	0.250	0.031
	19	23	0.0225		9,681			
10	49	27	0.0142	10,383	9,873	25	0.275	0.031
	19	21	0.0284		15,392			
8	51	25	0.0179	16,510	15,680	35	0.320	0.037
4	61	22	0.0253	41,741	39,193	70	0.420	0.0468
	61	20	0.0319		62,312			
2	127	23	0.0225	66,371	64,707	90	0.490	0.0468
	127	22	0.0253		81,598			
1	133	22	0.0253	83,693	85,453	100	0.600	0.0625
	127	21	0.0284		102,883			
0	133	21	0.0284	105,535	107,743	125	0.635	0.0625
	127	20	0.0319		129,731			
00	133	20	0.0319	133,077	133,817	150	0.700	0.0625
	259	23	0.0225		131,961			

VI. Specifications for Varnished Cambric Insulation Lighting and Starting Cables

Conductors shall be constructed as described in Section V, and shall be stranded as shown in Table 4.

Lighting and starting cables of this class shall have two or more layers of overlapping varnished cambric tape. Alternate layers shall be laid in opposite directions.

Lighting and starting cables of this class may be either single or double braided.

TABLE 5—ADDITIONAL SPECIFICATIONS FOR VARNISHED CAMBRIC INSULATION AND ARMORED LIGHTING AND STARTING CABLES

Nominal Size, A.w.g.	Continuous Carrying Capacity, Amp.	Maximum Outside Diameter Varnished Cambric Cables, In.	Maximum Outside Diam. Armored Cables, In.
16	8	0.215	0.255
14	18	0.229	0.269
12	22	0.249	0.289
10	27	0.273	0.313
8	45	0.298	0.338
4	80	0.383	0.423
2	110	0.450	0.496
1	140	0.530	0.576
0	180	0.570	0.616
00	210	0.629	0.675

VII. Specifications for Armored Lighting and Starting Cables

Conductors shall be constructed as described in Section V and shall be stranded as shown in Table 4.

Lighting and starting cables of this class shall have two or more layers of overlapping varnished cambric tape. Alternate layers shall be laid in opposite directions.

Lighting and starting cables of this class may be either single or double braided.

THE DISCUSSION

A. D. T. LIBBY:—It has been the task of the Subdivision that prepared this proposal to develop a new specification more in line with present automotive practice. The proposal does not include any electrical tests as the Subdivision does not feel that satisfactory electrical tests have been devised for automotive high-tension insulated cable. Many types of rubber-insulated wire and cable now on the market can be subjected to a high-voltage test at, for instance, 60 cycles, and some will break down at 20,000 volts, while some will withstand as much as 25,000 volts. Yet, when such cable is tested under certain conditions with the high frequency of the ignition system, the cable that shows the higher break-down voltage when subjected to the regular test at 60 cycles, will fail much more

quickly than a cable which would break down at a lower voltage.

W. S. HAGGOTT:—I have a letter from Mr. Burley, one of the members of the Subdivision which prepared this report, referring to the note under table 2, stating that the 7-mm. size is recommended for all high-tension cable. Mr. Burley writes:

> I do not agree with this recommendation. In the first place, it seems to me that it is not the function of these specifications to advise which size of high-tension cable to use, and, secondly, I think the 9-mm. size is more reliable than 7-mm. about in proportion to the difference in cost. The 9-mm. is called for by several of the best informed electrical engineers connected with the automobile plants. Nearly one-half of the plain rubber high-tension cable we make is in the 9-mm. size. I wish to dissent from the recommendation.

Although we do not find that the 9-mm. size is 50 per cent of our high-tension cable production, a large quantity of it is used, and I see no objection to deleting the reference note in the proposal.

MR. LIBBY:—Although the 9-mm. cable is used in the manufacture of ignition systems, the greater portion of it seems to be 7 mm. and judging from all the tests that I have made in the laboratory and elsewhere, the 7-mm. cable seems to be perfectly satisfactory. It is the size that has become standard on motorcycles, on which the cables are subjected to mud, oil, sunlight and water and have to stand up under much more severe service than on an automobile. In view of the fact that the large bulk of the cables seems to be of the 7-mm. dimension, it would seem advisable to retain the footnote.

H. T. WREAKS:—Our experience with the 9-mm. size was one of development due to the 7-mm. cable as made having failed to meet conditions on certain prominent makes of automobile on which the duty happened to be particularly heavy. It seems to me that simply to make this recommendation does not help the specifications in any way, and to do so would reflect more or less upon the practical experience of the manufacturers who have found a need for the 9-mm. cable and made all their dies and fittings for it.

W. A. CHRYST:—I believe the specification should favor the 7-mm. cable not so much on account of the changes in the size of wire as of price and to keep the number of sizes of terminals and fittings which go on the electrical equipment at a minimum.

At the present time ignition manufacturers have to make dies for 9-mm. as well as 7-mm. cable. There is nothing in the recommendation which prevents using the 9-mm. size, but where the matter is open there is no hesitancy in recommending the use of the 7-mm. size.

I can confirm Mr. Libby's remarks. In the case of motorcycles and airplanes, where the service is apparently very much more severe than on automobiles, no criticism has ever been brought against the 7-mm. cable.

MR. WREAKS:—Is there any reason for specifying that where lighting and starting cables are specified, they are limited to varnished cambric tape? Much rubber-covered armored cable is made and used.

MR. HAGGOTT:—I am of the opinion, which I think is concurred in by other cable manufacturers, that it is possible to make a good rubber-covered armored cable which will meet all of the possible requirements of starting and lighting service, but I think that the rubber-covered armored cable construction has not been developed to the point where it ought to be considered for a standard. Sometime an armored rubber-covered cable will be developed that will probably be as satisfactory as the present varnished cambric construction.

MR. STRICKLAND:—I notice that it is specified in the recommendation that high-tension cable should be rubber-covered. No provision is made for composition coverings, of which there are possibly several that are just as good as or better than rubber.

MR. LIBBY:—That is covered in the proposal, under

> High-tension ignition cables shall be plain rubber covered, single braided, rubber face taped and single braided or double braided.

(5) *Electrical Equipment Nomenclature*

Last fall it was suggested that the S. A. E. Standard Automobile Nomenclature for electrical equipment be revised to include terms applying to equipment which have been developed and come into general use since the present standard was adopted. The Division appointed a Subdivision to review this part of the standard nomenclature and to prepare a report which would bring it up-to-date. This report has been submitted to and reviewed by the Electrical Equipment Division and the recommendation approved for adoption by the Society. The report refers to the Divisions and Groups indicated, which are printed on pages K8 and K9, Vol. I, S. A. E. HANDBOOK.

DIVISION VII—IGNITION

Group 1—(Same as present standard)
Group 2—Battery Ignition Equipment

- Ignition Set
- Ignition Coil
- Ignition Switch
- Timer-Distributor
- Breaker-Arm
- Breaker Contacts
- Breaker Cam
- Distributor Rotor
- Distributor-Rotor Brush
- Distributor Cap
- Timer-Distributor Shaft
- Timer-Distributor-Shaft Gear
- Ignition Drive-Shaft
- Ignition Drive-Shaft Gear
- Manual-Advance Arm
- Automatic-Advance Element
- Ignition Unit, Magneto-Base Mounting

Group 3—Magneto (Same as present standard)
Group 4—(Omitted)

DIVISION VIII—STARTING AND GENERATING EQUIPMENT

General

- A single-unit system comprises a starter-generator
- A separate-unit system comprises a generator and a starting motor separately mounted
- A combined-unit system comprises a duplex starter-generator, an ignition-generator, or an ignition-starter-generator
- Direction of rotation is "clockwise" or "counter-clockwise" as determined by the driven shaft for magnetos, generators, starter-generators, and by the driving shaft for starting motors
- Methods of mounting units are: flange, base, strap and sleeve

Group 1—Generator

- Generator
- Generator Main Brush
- Generator Main Brush-Holder
- Generator Third Brush
- Generator Third Brush-Holder
- Generator Field Frame

Generator Field Fuse
Generator Driving Gear or Sprocket
Generator Shaft
Generator Coupling (Members as indicated under Magneto Coupling)

Group 2—Starting Motor

Starting Motor
Starting-Motor Brush
Starting-Motor Brush-Holder
Starting-Motor Pinion
Starting-Motor Intermediate Gear
Starting-Motor Intermediate-Gear Shaft
Starting-Motor Intermediate Pinion
Manual Shift
Screw Shift
Magnetic Shift

Group 3—Starter-Generator (Parts covered by Division VIII, Groups 1 and 2. Group 3 in the present standard is omitted.)

Group 4—Ignition-Generator (Parts covered by Division VII, Group 2, and Division VIII, Group 1.)

Group 5—Ignition-Starter-Generator (Parts covered by Division VII, Group 2, and Division VIII, Groups 1 and 2.)

Group 6—Battery (Same as Group 4 in present standard.)

DIVISION IX—MISCELLANEOUS ELECTRICAL EQUIPMENT

Group 1—(Same as the present standard except as revised by the Lighting Division.)

Group 2—Switches and Instruments

Lighting Switch
Starting Switch
Ignition Switch
Combined Switch (Such as lighting-ignition)
Ammeter
Voltmeter
Volt-Ammeter
Charging Indicator
Cut-Out Relay
Cut-Out Relay Contacts
Cut-Out Relay Armature
Cut-Out Relay Shunt Coil
Cut-Out Relay Series Coil
Current Regulator
Voltage Regulator
Starting-Switch Contacts
Starting-Switch Contactor
Starting-Switch Plunger (Lever or Button)
Through-the-Board Mounting
Front-of-Board Mounting
Ground-Return Wiring
Insulated-Return Wiring

Group 3—Horn

Motor-Operated Horn
Vibrator Horn
Hand Horn
Horn Projector
Horn Diaphragm
Horn Sound Ratchet
Horn Motor

Group 4—Miscellaneous (Same as the present standard)

THE DISCUSSION

MR. STRICKLAND: — In the proposed nomenclature timer-distributor might better be called ignition-distributor, which is a term more generally used.

MR. LIBBY:—The Division discussed that point and finally agreed that timer-distributor is the better term to use, because the timer is built into the distributor in the majority of cases. That is to say, there is the distributor head, underneath the head is the distributor finger, and usually below that is the timer which determines the time at which the spark takes place.

MR. HORINE:—Why call it a timer on a battery system and a breaker on a magneto system?

MR. LIBBY:—This is largely a matter of usage. In connection with a distributor it is called a timer-distributor, but there is not exactly the same arrangement on a magneto, where the part has always been referred to as a breaker, never as a timer.

MR. HORINE:—In the old battery systems there was a timer which looked very much like a distributor. There is some danger of confusion in this connection.

MR. STRICKLAND:—The term timer-distributor has not been employed at all by users, I think. Possibly it has been used by magneto manufacturers.

MR. CHRYST:—I think that none of the manufacturers uses as a whole the terms recommended. This proposal was the best compromise that would be intelligible to all the manufacturers. It is customary for some to call the complete unit a distributor, while others call it a battery system, but to describe this apparatus definitely, without being too verbose, the name timer-distributor seemed to fit as well as anything.

C. E. WILSON:—We call it either a timer or a distributor but do not use the two terms together.

MR. CHRYST:—That is what we found among the members of the Division, and it seemed that timer-distributor was the best compromise, because it describes the apparatus accurately and is something we could all agree on.

H. E. CLAY:—I notice that the report refers to timer-distributor and then in naming the related parts mentions breaker-arm, breaker contacts, breaker cam, distributor rotor, distributor-rotor brush and distributor cap. Would not breaker-distributor do?

MR. LIBBY:—There seems to be some misunderstanding regarding this term. As Mr. Chryst has pointed out, this apparatus is known in different factories by various names, and the proposed term is more or less of a compromise. A timer-distributor is the complete unit, comprising the breaker-arm, breaker contacts, breaker cam, distributor rotor, distributor-rotor brush, distributor cap, the shaft, and the whole assembly ready to install in an automobile.

MR. STRICKLAND:—The term distributor being used, to be consistent the word timer should be eliminated and the head called a distributor.

MR. LIBBY:—The unit is either an ignition distributor or a timer-distributor.

W. M. BRITTON:—The definition as recommended by the Division tells the whole story; it is a timer and distributor combined. The word distributor would designate a distributor alone without the combination of a breaker or timer of any description. In other words, in a magneto there is a distributor as one unit and also a breaker-box containing a breaker. It is not a combination unit, as called for and designated by this nomenclature. I believe the nomenclature should stand exactly as recommended.

A. J. SCAIFE:—I believe it is superfluous to call it that; it sounds like "free gratis." When you refer to distributor, you refer to the whole instrument, and there is no other part of the car that it can be confused with. There is nothing on the car which has anything like that same name, and when talking about a distributor, you mean a distributor or timing device.

G. W. DUNHAM:—A few years ago, when we had air starters, we had an air distributor. We do not know that we shall not have other kinds of distributor. At the present time, I think, there are oil distributors. Distributor is a broad term which means nothing unless

there is some other word with it to explain what kind of a distributor is meant.

MR. BRITTON:—One type of magneto now being built has a distributor similar to that used on battery systems so far as the distributor is concerned. If this nomenclature is changed to distributor, it would designate that type of unit. That is not what is meant at all. The reference is to a combination unit, a timer for the primary system and a distributor for the secondary system.

P. M. HELDT:—Instead of the word timer, I think we should use breaker. Timer is an old word and is not used any more.

CHAIRMAN BACHMAN:—You have a Division which has worked on this subject. Nine of them have voted "yes"; none of them has voted "no"; two of them have not voted. These men are well acquainted with this situation, have sat together in a small meeting, and have thought this thing out. You have their recommendation. There is no doubt that there is a reason for a division of opinion on the matter, and probably the ideas you have expressed here are as good as those your Division has reported. The thing to do is to vote according to what you think the term should be.

(6) *Magneto Couplings*

The present standard for magneto flexible-disc couplings printed on page B14, Vol. I, S. A. E. HANDBOOK, was criticised at the January Standards Committee Meeting as being too distinctive of but one type of coupling, and was referred back to the Electrical Equipment Division for further consideration. The Division has investigated the various types of coupling in more or less common use, and recommended that the present standard for magneto flexible-disc coupling be cancelled, and that the following note be substituted under the drawing of the S. A. E. Standard Magneto Mounting on page B14

> Magneto couplings shall be 2⅜ in. long and have an outside diameter not greater than 3¼ in.

The Electrical Equipment Division has recommended to the Parts and Fittings Division that a standard be formulated for a complete line of flexible-disc couplings.

ENGINE DIVISION REPORT

(7) *Carbureter Flanges—Cast-Iron Type*

The Engine Division's recommendation that the present S.A.E. Recommended Practice for cast-iron carbureter flanges be cancelled has been approved. The present recommended practice reads:

> The flange dimensions for each nominal size cast-iron or oversize carbureter shall be the same as the flange dimensions for the next larger size two or four-bolt carbureter given on pages A8 and A9.

This recommended practice was formulated by the Stationary Engine and Lighting Plant Division in 1919 at which time cast-iron carbureters were coming into use for stationary and tractor engines.

(8) *Carbureter Flanges—Two-Bolt Type*

Experience has indicated that cast-iron carbureter and fitting flanges made to the dimensions given in the S.A.E. Recommended Practice printed on page A8, Vol. I, S.A.E. HANDBOOK, but with the flanges somewhat thicker than for brass, are satisfactory for all general purposes. Such practice makes unnecessary the oversizing of flanges for cast iron. The following recommendation of the Engine Division was approved for inclusion in the present recommended practice.

> When carbureter and fitting flanges are made of brass, their dimensions shall conform to the accompanying table. When they are made of cast iron, the flange thickness, dimensions *F* and *G*, shall be increased ⅛ in. for all sizes.

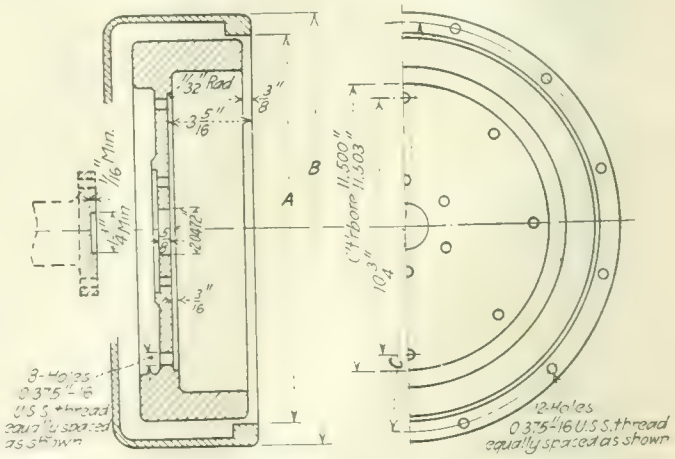
(9) *Disc-Clutch Flywheel Housings*

The Engine Division received a request from one of the transmission manufacturers to include a dimension for the thickness of the flywheel web where it is bolted to the crankshaft of the engine, inasmuch as considerable inconvenience has been caused with regard to fitting the pilot bearing into the present standard bore of 2.0472 in.

Data were collected of dimensions used on the principal makes of engine, and the Division's recommendation approved to add the following dimensions to the present S.A.E. Standard for Disc-Clutch Flywheel Housings printed on page A1, Vol. I, S.A.E. HANDBOOK.

> Crankshaft flange counterbore: minimum diameter, 1¾ in.; minimum depth, 1/16 in.
> Flywheel web thickness of counterbore: ⅝ in.
> Clutch counterbore in flywheel: diameter limits, 11.500 and 11.503 in.; depth, 3/16 in.; corner radius, 1/32 in.

The dimensions for crankshaft flange bolt clearance space have been added to the drawing and accord with the dimensions adopted at the Annual Meeting of the Society.



Size No.	A	B	C
1	20½	21¾	20⅞
2	17⅝	19¼	18⅜
3	16½	17¾	16⅞
4	14¼	15⅞	15
5	12⅝	14	13⅛

The minimum diameter of the clearance space for crankshaft flywheel bolt-heads shall be 6⅛ in. and the minimum depth ⅝ in.

All dimensions in inches. Fixed dimensions do not apply to size No. 5.

THE DISCUSSION

S. O. WHITE:—The report specifies a tolerance of 0.003 in. on an 11½-in. diameter counterbore. Would there be any objection to changing that tolerance from plus 0.003 in. to plus 0.002 in.?

J. B. FISHER:—The tolerance of 0.003 in. is necessary on account of the large diameter. It is much easier to hold to a 0.003-in. limit on a piece that is ground to size than on a large flywheel disc machined on the Bullard or

other heavy-duty machines of that type. Three-thousandths of an inch is about the minimum tolerance that the engine builders can work to in such places.

T. C. MENGES:—How much clearance will that counterbore give for the outside of the bolt-heads?

MR. FISHER:—One-sixteenth of an inch at all points, on the sides and at the end.

ISOLATED ELECTRIC LIGHTING PLANT DIVISION REPORT

(10) *Rating of Storage Batteries*

In August, 1919, the Society adopted the present standard printed on page B37, Vol. I, S.A.E. HANDBOOK, as a result of the proposal formulated by a Subdivision of the Electrical Equipment Division and approved by the Electrical Equipment Division. The present standard was approved by the isolated electric lighting plant manufacturers as represented by that group in the Gas Engine and Farm Power Association (then the National Gas Engine Association). About one year later this group of the Gas Engine and Farm Power Association held a meeting at which the misunderstandings and confusion which had arisen between the manufacturers and their customers, were discussed. The majority of lighting plant manufacturers who participated felt that the standard was unsatisfactory, and formally requested the Isolated Electric Lighting Plant Division to recommend the cancellation of the present standard and to formulate a new one which would be simpler and suitable for adoption by all the lighting plant manufacturers. The Division has given this subject careful consideration and has held several meetings at which non-members of the Division representing the lighting plant and storage battery manufacturers have been present. Early this year a meeting was held at which it was agreed that the lighting plant manufacturers would consider some rating for storage batteries expressed in terms of watt-hours or kilowatt-hours in order that the rating might be expressed in the same terms as the ratings used for electrical equipment operated on isolated electric lighting plants, such as vacuum cleaners, washing machines, sad irons and electric incandescent lamps. At a subsequent meeting other suggested ratings were carefully considered, among which was one expressed in terms of the hours of discharge of the battery when discharged at a constant rate corresponding to 300 watts or fifteen 20-watt lamps, based on a nominal voltage of 2 volts per cell.

It was understood that this new method of rating could be readily adopted by the lighting plant manufacturers who are at present using different methods, such as the 72-hour intermittent and the constant 8-hour discharge ratings. It was thought very desirable to have a common rating which could be universally adopted and conformed to by the lighting plant manufacturers. It was realized that the proposed new rating would be used very largely as a commercial one, although it would enable the user of the plants to make reliable comparative tests on the batteries he buys.

The recommendation of the Division was referred to a meeting of the Farm Lighting Plant Group of the Gas Engine and Farm Power Association held in Chicago April 28 with the intention of securing unanimous approval of the Division's proposal by all the lighting plant manufacturers. It was approved in general at this meeting except that the discharge rate was reduced to correspond to 200 watts or ten 20-watt lamps instead of 300 watts. The recommendation of the Division was therefore printed in two sections and each considered separately by the Standards Committee and Society.

[Section 1 of the recommendation as printed below was approved. Section 2, which referred to the adoption of a new rating, was referred back to the Division. This section of the recommendation together with the discussion at the Standards Committee meeting is printed on page 70 of this issue of THE JOURNAL under the recommendations which were not accepted by the Standards Committee.]

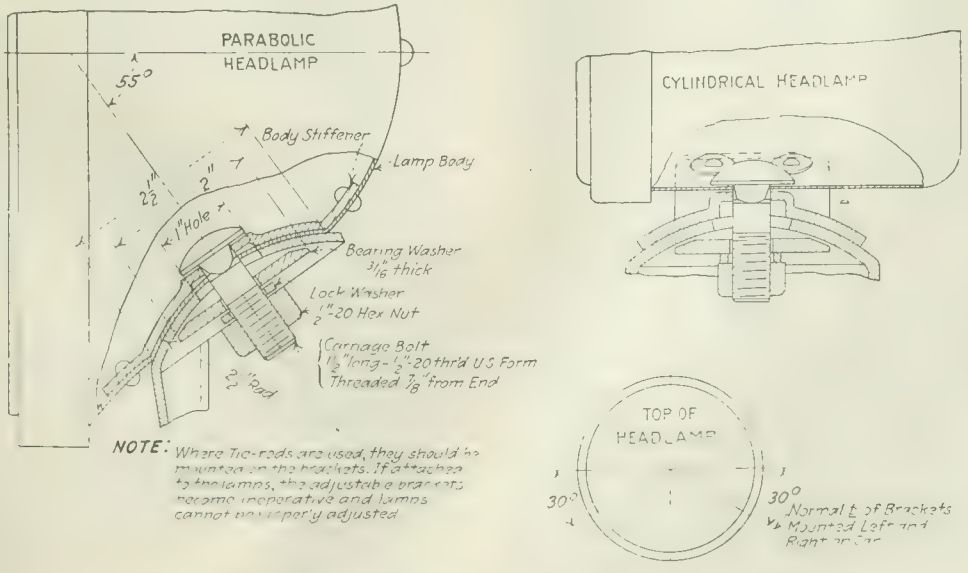
SECTION 1

The Isolated Electric Lighting Plant Division recommends that the present S. A. E. Standard "Rating of Storage Batteries" printed on page B37, Vol. I, S.A.E. HANDBOOK, be cancelled.

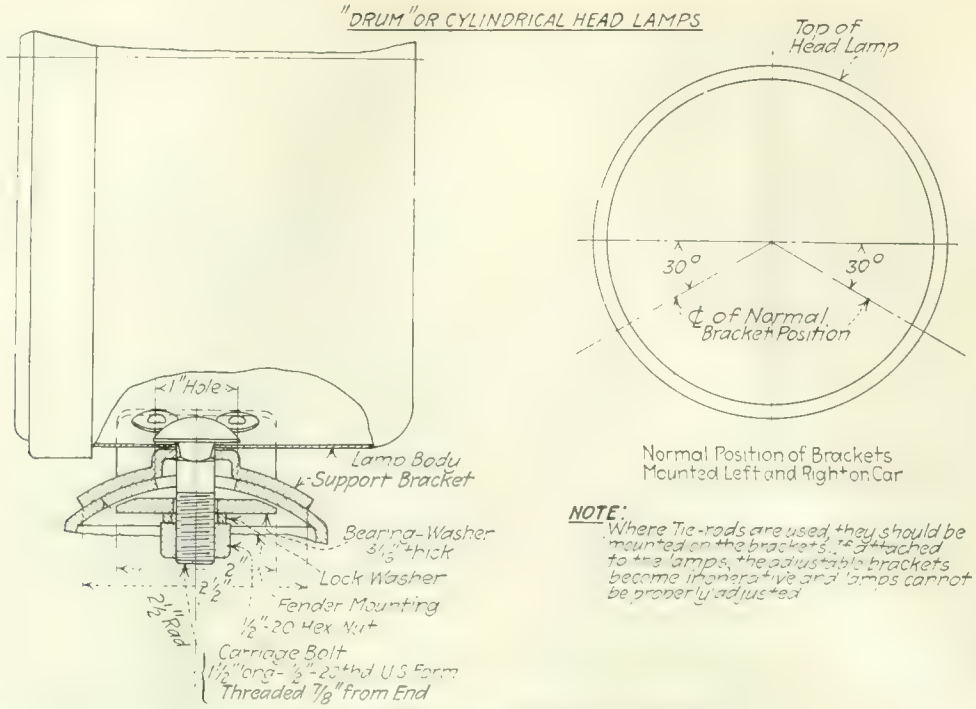
LIGHTING DIVISION REPORT

(11) *Head-Lamp Brackets*

In August, 1920, the Society adopted a recommendation formulated by the Lighting Division for a fender type of head-lamp bracket. This recommendation applied to the bolt-hole dimensions for attaching the bracket to the fender and was approved, as it was thought that it would do much to bring about the adoption of a universal type


PARABOLIC HEADLAMP
55°
Body Stiffener
Lamp Body
2 1/2"
2"
1" Hole
Bearing Washer 3/16" thick
Lock Washer
1/2"-20 Hex Nut
Carriage Bolt 1 1/8" long - 1/2"-20 thrd U.S. Form Threaded 7/8" from End
2 1/2" Rad
NOTE: Where Tie-rods are used, they should be mounted on the brackets. If attached to the lamps, the adjustable brackets become inoperative and lamps cannot be properly adjusted
CYLINDRICAL HEADLAMP
TOP OF HEADLAMP
30°
30°
Normal to Brackets When Mounted Left and Right on Car

PROPOSED PARABOLIC HEAD-LAMP BRACKET
Brackets shall be fastened to the fenders by two 3/8-in. bolts set 3 in. apart center to center


"DRUM" OR CYLINDRICAL HEAD LAMPS
Top of Head Lamp
30°
30°
℄ of Normal Bracket Position
Normal Position of Brackets Mounted Left and Right on Car
NOTE: Where Tie-rods are used, they should be mounted on the brackets. If attached to the lamps, the adjustable brackets become inoperative and lamps cannot be properly adjusted
1" Hole
Lamp Body Support Bracket
Bearing-Washer 3/16" thick
Lock Washer
Fender Mounting
1/2"-20 Hex Nut
Carriage Bolt
1 1/2" long - 1/2"-20 thd U.S. Form Threaded 7/8" from End
2" Rad
2 1/2"

PROPOSED CYLINDRICAL HEAD-LAMP BRACKET
Brackets shall be fastened to the fenders by two 3/8-in. bolts set 3 in. apart center to center

of mounting on which the Lighting Division was working at that time.

As a result of a large amount of work by the Lighting Division and the lamp manufacturers in cooperation with a number of automobile engineers, a universal fender-type head-lamp bracket has been developed and found satisfactory in actual practice. It will permit the universal adjustment of the lamp and interchangeability of lamps.

The Lighting Division's recommendation will supersede the present recommended practice for the fender-type head-lamp mounting, page B1, Vol. I, S.A.E. HANDBOOK.

THE DISCUSSION

MR. WOOLER:—What is to prevent the bolt from backing out and damaging the reflector?

C. E. GODLEY:—A piece riveted on the inside keeps the bolt from coming out. This is not shown on the drawing in the report as such details are left to the lamp manufacturers.

MR. WOOLER:—How will all lamp manufacturers know about it unless it is shown or mentioned?

MR. GODLEY:—This proposal refers only to the adjustable and interchangeable features of the bracket.

MR. CHRYST:—Is this a patented arrangement?

MR. GODLEY:—No.

(12) *Motorcycle Head-Lamp Mounting*

The Lighting Division's recommendation that the present S.A.E. Standard for Motorcycle Head-Lamp Mounting, page B2, Vol. I, S.A.E. HANDBOOK, be extended to specify 5½ in. between the centers of the bracket prongs was approved. This dimension is used by most of the motorcycle manufacturers at the present time and will make the existing standard much more effective in interchangeability of motorcycle head-lamps.

(13) *Lamp Nomenclature*

As the many variations in the manner of specifying types of lamps has caused a good deal of misunderstanding and trouble for lamp manufacturers and users, the standardization of lamp nomenclature in respect to type, position and use has been worked out by the Lighting Division. It was felt that the nomenclature should indicate the several general types of lamps only, as there are several variations of different types which are usually fully described in the purchase specifications, the purpose of the proposal being to establish common terms which will be used by everybody.

Head-Lamp.[1]—A lighting unit on the front of a vehicle intended primarily to illuminate the road ahead of the vehicle.

Side-Lamps.[2]—A lighting unit mounted on either side of a vehicle and intended primarily as a marker to indicate the location of the vehicle.

Tail-Lamp.—A lighting unit used to indicate the rear end of a vehicle by means of a ruby light.

Backing-Lamp.—A lighting unit mounted on the rear end of a vehicle and intended to illuminate the road to the rear.

Spot-Lamp.—A lighting unit mounted on a manually operated adjustable bracket, which has one focusing type reflector and one focusing type light source.

Instrument-Lamp.—A lighting unit mounted on the instrument-board and intended to illuminate the instruments.

Dome-Lamp.—An interior lighting unit mounted in the top of a vehicle.

Panel-Lamp.—A lighting unit mounted either in the rear panel or in the corners of a closed vehicle.

Tonneau-Lamp.—A lighting unit mounted in the back of the front seat in open or closed vehicles.

Step-Lamp.—A lighting unit mounted on the exterior of a vehicle and intended primarily to illuminate the step or running-board.

Hood-Lamp.—A lighting unit mounted under the

[1] Head-lamps may be divided into three general types: single-socket, a lamp having one focusing type reflector and one focusing type light source; two-socket, a lamp having one focusing type reflector and one focusing type and one auxiliary light source; and duplex, a lamp having two focusing type reflectors and two focusing type light sources.

[2] Side-lamps cover such types as are generally known as bullet, cowl, fender or parking, pillar or windshield lamps.

hood of a vehicle to illuminate the engine compartment.

Inspection-Lamp.—A portable lighting unit connected by an extension cord to the lighting system of a vehicle.

(14) *Bases, Sockets and Connectors*

The Subdivision on Bases, Sockets and Connectors formulated revisions of the present S.A.E. Standard for Bases, Sockets and Connectors, pages B4 and B5, Vol. I, S.A.E. HANDBOOK, which the Lighting Division members have carefully reviewed and consider will bring the present standard into accord with the best engineering practice. The recommendation of the Division was approved and includes the following changes:

Bases.—Specify a dimension of 0.040 in. as a maximum height of solder on the finished lamp to prevent having a heavy slug of solder on the lamp base.

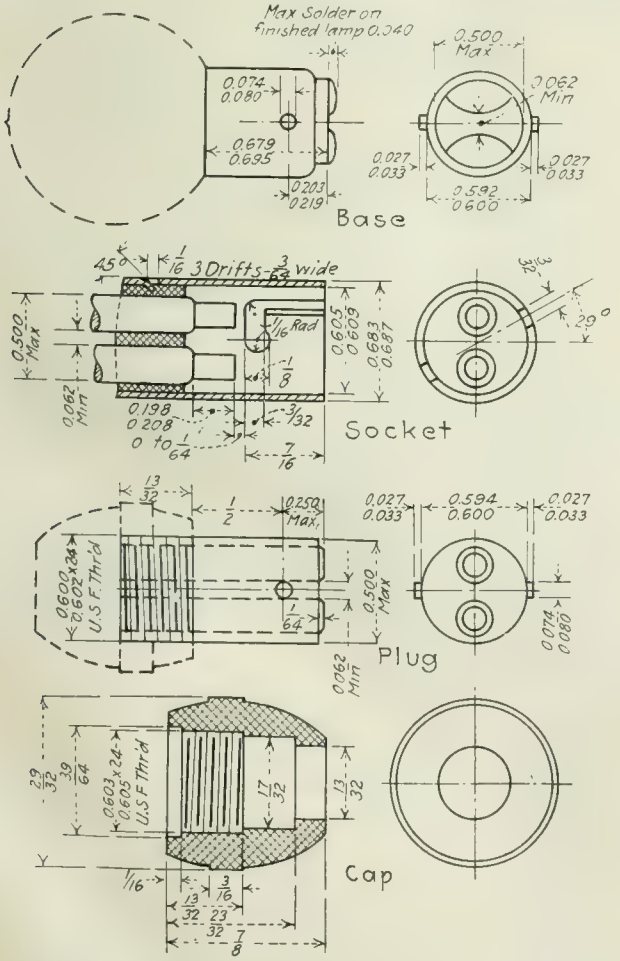
Plugs.—Change the thread limits for the plugs from 0.603 to 0.605 in. to 0.600 to 0.602 in. to permit better assembly, as a maximum-size plug is too large to properly fit a minimum-size cap.

Change the projections of the brass inserts from 1/32 to 1/64 in. to permit the plug to turn into the connector without interfering with the plungers of the insulated-return or two-pole type.

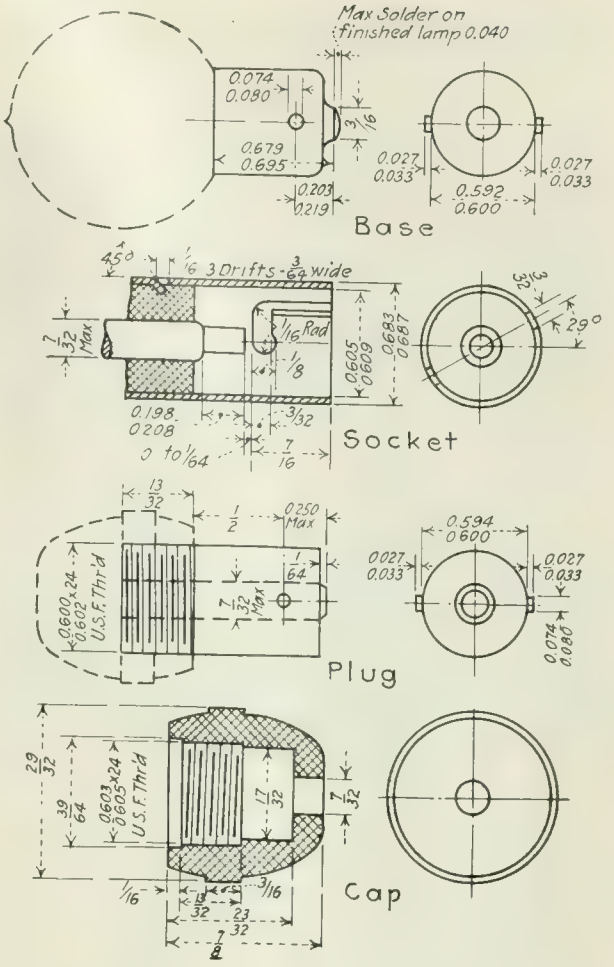
Sockets.—Change the length of the plungers from 0.281 in. minimum to 0.198 to 0.208 in. in order to conform to present practice and to eliminate unnecessary travel of the plungers.

Change the location of the bottom of the bayonet slot with relation to the ends of the plunger to limits 0 to 1/64 in. to conform to the shorter plungers.

Change the angle of the center-line of the slots to the center-line of the pins when locked from 39 to 29 deg.



INSULATED-RETURN TYPE BASES, SOCKETS AND CONNECTORS



GROUND-RETURN TYPE BASES, SOCKETS AND CONNECTORS

to conform to present practice and prevent die breakage.

Include the following recommended method of assembling the core in the tube: Three drifts shall be used and shall be approximately 3/64 in. wide, 1/16 in. long and drifted in at an angle of 45 deg. All drifts shall be made laterally and at one operation to prevent distorting the tube.

The present S.A.E. Standards for the ground-return and insulated-return type bases, sockets and connectors, revised as proposed above, are given in the accompanying illustrations.

PARTS AND FITTINGS DIVISION REPORT

(15) *Exhaust Pipes*

The Parts and Fittings Division's recommendation for S.A.E. Recommended Practice was approved in accordance with the following:

> The outside diameters of exhaust pipes extending from the engine to the muffler shall conform to the following steel-tubing sizes: 1, 1¼, 1½, 1¾, 2, 2¼, 2½, 2¾, 3, 3¼, 3½ and 4 in.

This recommendation was formulated in order to reduce the large number of exhaust-pipe diameters used in present practice and make it unnecessary for the muffler and exhaust-heater manufacturers to provide for an unnecessarily large number of sizes. Such a standard will be appreciated by the tubing mills and will facilitate deliveries and stocking. The recommendation is intended to apply to future production and is based on a survey

of present practice which indicated that the 1⅝, 1¾, 2, 2¼, 2½, 2⅝ and 3-in. steel-tubing sizes are most generally used.

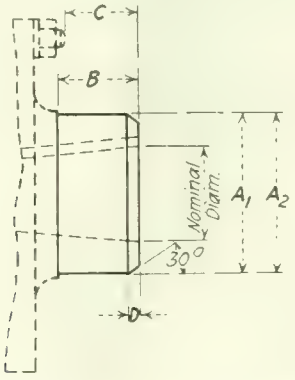
(16) *Square Shaft Fittings*

The Parts and Fittings Division's recommendation that the present S.A.E. Standard for Square Shaft Fittings, page C12, Vol. I, S.A.E. HANDBOOK, be revised so that the shaft-end and nut dimensions conform to the shaft-end and nut dimensions of the present S.A.E. Standard for Taper Fittings with Plain and Slotted Nuts, was approved.

The latter standard was revised in August, 1920, in order that the nut dimensions and threads might conform to the S. A. E. Standard regular thread pitch and U. S. Standard nut dimensions and thus permit the use of standard wrenches as well as facilitate the purchase of stock.

(17) *Universal-Joint Hubs*

In order to obtain better interchangeability between universal-joints and transmissions, the Parts and Fittings Division recommended adoption as S.A.E. Recommended Practice of the universal-joint hub dimensions given in the accompanying table. The dimensions specified are of importance to the transmission manufacturers by eliminating many present variations in these parts, and to the transmission purchasers by making available transmissions having standardized shaft-ends.



Nominal Diam	Hub Diameter: Lathe Finish (A_1) Max.	Lathe Finish (A_1) Min.	Ground Finish[3] (A_2) Max.	Ground Finish[3] (A_2) Min.	Minimum Finished Length (B)	C[4]	D
⅞	1.280	1.270	1.253	1.250	⅝	9/16	1/2
⅞	1.530	1.520	1.503	1.500	¾	5/8	3/4
1	1.780	1.770	1.753	1.750	¾	¾	1 16
1¼	2.030	2.020	2.003	2.000	⅞	¾	1 16
1¼	2.155	2.145	2.128	2.125	⅞	¾	1 16
1½	2.280	2.270	2.253	2.250	1	¾	1 32
1½	2.530	2.520	2.503	2.500	1	¾	1 32
1¾	3.030	3.020	3.003	3.000	1¼	15/16	1⅛
2	3.280	3.270	3.253	3.250	1½	1 3/16	1⅛

All dimensions in inches.

[3]When specified the maximum eccentricity of the ground surface with respect to the hole shall be 0.002 in. (indicator reading 0.004 in.).

[4]The transmission design should provide clearance for the least distance from the end of the hub to the end of the flange bolt.

All fittings shall be S. A. E. Standard taper or spline fittings. The nominal diameter applies in either case.

The original recommendation of the Division, which was circularized among the universal-joint, transmission, passenger-car and motor-truck manufacturers, specified dimensions for the outside diameters of the universal-joint companion flange in order to permit the transmission designer to lay out the gearshift rods so that they would clear the companion flange. Criticisms received, however, indicate that the large number of different types and sizes of companion flanges would not permit specifying outside diameters without affecting individual design.

It is planned to have the Parts and Fittings Division formulate a standard for a complete series of flexible-disc couplings, which will be of value in this connection as well as for other purposes.

SCREW-THREAD DIVISION REPORT

(18) *Drain-Cocks*

As radiator manufacturers and users have experienced trouble in draining radiators, due to sediment stopping up the small passage in many drain-cocks, and as the diameter of the passage varies considerably for the same size cocks, the subject was assigned to the Screw-Thread Division for consideration at the request of the Radiator Division. It was believed the diameter of the drain-cock passage for the different connection thread sizes should be definitely standardized.

The Screw-Thread Division secured data from the drain-cock manufacturers and the following recommendation for S.A.E. Recommended Practice was approved. The recommendation applies to drain-cocks intended for general use where these sizes are applicable, and is not limited to radiator applications.

Thread Size[5]	Passage Diameter, Minimum[6]
⅛	5/32
¼	1/4
⅜	11/32
½	7/16

[5]American Standard Taper Pipe Thread.

[6]The sectional area of the passages throughout their length shall be not less than that obtained with the minimum diameters given in the accompanying table.

STATIONARY ENGINE DIVISION REPORT

(19) *Stationary Engine Belt Speeds*

The Stationary Engine Division has considered the standardization of belt speeds for stationary engines and power-driven implements, one of the most important subjects before it. A survey of present practice was made which indicated variations of belt speeds used by different manufacturers of engines and implements, these variations having an extensive effect on pulley manufacturers also. A number of horsepower-belt-speed curves were developed in order to have a definite belt speed for each engine size, and the present proposal was finally arrived at. The curve of these values is developed by the hyperbolic formula

$$(x - 400)\cdot \quad 160{,}000\ (y - 1\tfrac{1}{2})$$

where

x = Nominal engine horsepower

y = Belt speed in feet per minute

and lies very close to the averages of present practice throughout its range.

The Stationary Engine Division's recommendation of the adoption of the belt speeds given in the accompanying table for stationary internal-combustion engines and for power-driven agricultural implements was approved.

Belt speeds are not specified above 16 hp. as there is a

tendency toward using tractor power for power-driven machinery requiring more than 12 hp. to which the present S.A.E. Standard tractor belt speeds of 1500, 2600, 3000 and 3500 ft. per min. apply.

STATIONARY ENGINE BELT SPEEDS

Nominal Engine Rating, Hp.	Belt Speed, Ft. per Min.	Nominal Engine Rating, Hp.	Belt Speed, Ft. per Min.
1½	550	7	1340
1¾	600	8	1420
2	680	9	1500
2½	800	10	1575
3	900	12	1700
4	1030	14	1810
5	1150	15	1860
6	1250	16	1910

THE DISCUSSION

MR. MENGES:—In connection with the report on belt speeds 23 different manufacturers were consulted. These speeds are the average of those used at present. An attempt was made to keep speeds within certain limits, but as it was found impossible to do so, the best thing under the circumstances was to take the average belt speed for each size stationary engine.

G. W. GILMER:—Transmitting power by belt is one of the oldest subjects that this Division has taken up. It is, I believe, one about which there is little general information. There are two generally accepted ways of compensating for changes of power in a belt. One is by changing the diameter of the pulley, thereby changing the speed, and the other is by changing the width of the belt. The latter is not in accordance with the best and most economical method of transmitting power. There are certain speeds at which engines operate most economically and satisfactorily. With reference to general power transmission, belt speeds between 1800 and 2500 ft. per min. are most desirable. If belt widths can be kept the same, and pulley diameters changed so as to maintain these belt speeds, approximately much better results will be had.

Belts running at low or very high speeds are not economical. None of the belt speeds given in the report comes up to the most economical speed for power transmission. I am a manufacturer of power belting and have been studying the subject for a number of years, longer than I have been a member of this Society, and I feel that if the speeds recommended by the Division are established, it will be necessary to change them in the future.

MR. MENGES:—We did not take into consideration what speeds would be the best and most efficient for the belts. The speeds recommended are an average of those used at the present time by the different engine builders. So far as power is concerned, it must be taken into consideration that the smaller engines drive slow-moving machines, are cranked usually by hand and operate at from 60 to 80 r.p.m. Under such conditions it is not possible to put on the most efficient belting, as it would be so narrow and run at such high speeds as to not be practical for the farmer.

(20) *Stationary Engine Rating*

The Stationary Engine Division's recommendation that the accompanying horsepower formula be approved only as general information for publication in the S.A.E. HANDBOOK, as a means of securing uniform practice in commercially rating stationary engines, was acted upon favorably by the Standards Committee and the Society.

$$\text{Nominal Engine Horsepower} = \frac{0.7854\, D^2\, L\, R\, N}{13{,}000}$$

where

D = the piston diameter in inches
L = the stroke in inches
R = the revolutions per minute of the crankshaft
N = the number of cylinders

The formula is based on a piston displacement of 13,000 cu. in. per min. per hp., which is considered a very fair average factor for stationary and tractor engines burning either kerosene or gasoline. Various mechanical arrangements and refinements will, of course, influence the actual results on any one engine.

When the Tractor Division was originally working on this subject in 1919, the then tentative proposal, was submitted to and approved by the Stationary Engine Division as a satisfactory commercial or comparative rating for stationary internal-combustion engines, but failed of approval by the Standards Committee in June 1920 for adoption as S.A.E. Recommended Practice as being of a commercial rather than an engineering nature. It was approved, however, as general information.

The results obtained using this formula are almost exactly 80 per cent of the brake horsepower under average good conditions and provide the desired 20 to 25 per cent of reserve power. It is not intended that this formula shall be used in engineering calculations.

(21) *Lubricator Cups*

Members of the Stationary Engine Division have felt the need of a standard for stationary internal-combustion engine lubricator and, after obtaining and comparing data from the several manufacturers, the Division has formulated a series of lubricator cups, including the capacity, outside glass diameter, glass height and connection thread, which through its adoption will bring practice into accord. The report as recommended by the Division for S.A.E. Recommended Practice is given in accompanying table as approved by the Standards Committee.

LUBRICATOR CUP DIMENSIONS

Size No.	Capacity, Oz.	Outside Diameter of Glass, In.	Height of Glass, In.	Thread[7]
1	1	1 1/2	1 3/8	1/4-18
1½	1 1/2	1 3/4	1 5/8	1/4-18
2	2 1/2	2	1 7/8	3/8-18
3	4	2 1/4	2 1/8	3/8-18
4	5	2 1/2	2 3/8	3/8-18
5	10	3	3	1/2-14
6	18	3 1/2	4	1/2-14
8	32	4 1/4	5	3/4-14

[7]American Standard Taper Pipe Thread.

(22) *Stationary Engine Crankshafts*

It is felt by some of the stationary-engine builders that standard crankshaft and crankpin diameters will be of material benefit in reducing the number of sizes of shaft-mounted pulleys, bearings and other parts affected by these diameters, facilitate purchasing and machining of crankshaft stock, and enable engine manufacturers to make replacements more readily. A survey of present practice indicated that these dimensions are nearly the same for the different makes of engines in corresponding engine sizes and that the proposed standard can be readily adopted by the manufacturers in new designs.

In some instances alloy steels have been used which have permitted of reducing the shaft sizes to a certain extent, but in general present practice is to use a low-carbon steel as service conditions necessitate a rugged low-priced, reliable construction.

The Stationary Engine Division's recommendation given in the accompanying table was approved for adoption as S.A.E. Recommended Practice.

CRANKSHAFT AND CRANKPIN DIAMETERS FOR SINGLE-CYLINDER STATIONARY INTERNAL-COMBUSTION ENGINES

Cylinder Bore	Crankshaft and Crankpin Diameter	Cylinder Bore	Crankshaft and Crankpin Diameter
3	1 1/8	5 1/2	2 1/8
3 1/4	1 1/4	6	2 1/4
3 1/2	1 1/4	6 1/2	2 3/8
3 3/4	1 3/8	7	2 1/2
4	1 1/2	7 1/2	2 3/4
4 1/4	1 5/8	8	3
4 1/2	1 3/4	8 1/2	3 1/4
4 3/4	1 7/8	9	3 1/2
5	2	9 1/2	3 3/4
...	...	10	4

All dimensions in inches.

(23) *Water-Pot or Hopper Capacities*

As it is believed that the volumetric capacities in present stationary-engine water-pot practice is in general close enough to warrant the adoption of a definite recommended practice at this time, the Stationary Engine Division recommended that the accompanying table of water-pot or hopper capacities be adopted as S.A.E. Recommended Practice. Although there is some difference in these capacities for kerosene and gasoline engines, they are considered near enough alike to warrant but one series of standard capacities for all practical purposes. The accompanying table was accordingly approved by the Standards Committee.

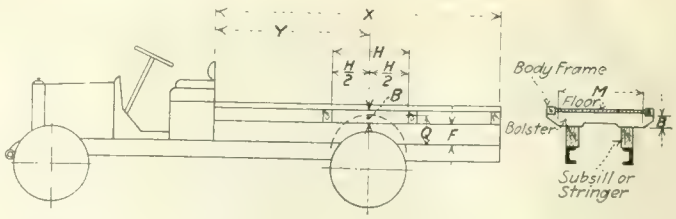
WATER-POT OR HOPPER CAPACITIES

Nominal Engine Rating, Hp.	Cooling Water Capacity, Lb.	Nominal Engine Rating, Hp.	Cooling Water Capacity, Lb.
1 1/2	15.0	7	85.0
1 3/4	17.5	8	105.0
2	20.0	9	130.0
2 1/2	25.0	10	160.0
3	30.0	12	225.0
4	40.0	14	310.0
5	55.0	15	360 0
6	70.0	16	420.0

TRUCK DIVISION REPORT

(24) *Motor-Truck Bodies*

The subject of motor-truck body-installation dimensions was first proposed to the Society about two years ago and assigned to the Truck Division. The original plan was to develop a standard which would include dimensions for the mounting of bodies on trucks and also frame widths, distance between spring-centers, wheel treads and turning radii. A Subdivision was appointed which obtained considerable data on the practice at that time. The work was delayed somewhat due to conditions which arose, and it was not until last fall that further data were secured and another careful analysis of existing conditions made. The original program has been reduced so that this proposal includes only dimensions



F (Subsill) = (Q + Chain Clearance) — B

Nominal Capacity, Tons	Body Bolster (B)	Length Back of Seat to End of Frame (X)	Length Back of Seat to Center-Line of Rear Axle (Y)	H[1]	Dimension of Bolsters (M)
3/4 to 1	5	108	60	32	36
1 1/4 to 1 1/2	5	120	72	36	38
2 to 2 1/2	5	132 156	81 98	36	38
3 to 4	5	144 192	90 114	36	42
5 to 6	5	144 192	90 114	36	42

[1] Dimension H permits a variation of plus or minus 2 1/2 in. of the rear axle from the normal position.

Q is measured from the top of the chassis to the top of the tires when the springs are deflected to the "metal to metal" position.

for the stringers, bolsters, distance from the back of the seat to the center of the rear axle and the distance from the back of the seat to the rear end of the frame. The dimensions were generally approved as suitable for the interchangeable mounting of truck bodies with the exception of special types such as large van bodies and special short dump bodies.

The proposal as submitted by the Truck Division for adoption as S.A.E. Recommended Practice and approved by the Standards Committee is shown in the accompanying drawing and table, and indicates the available space in which bodies may be mounted. The proposal also includes the nomenclature of the body mounting timbers, which at the present time are known by a variety of terms. It is believed that the proposal includes all the necessary dimensions for the installation of truck bodies by body builders on trucks conforming closely to the dimensions given in the table, and that it will answer the requirements for such standardization which had been urged through the technical press for some time.

(25) *Motor-Truck Hubs*

In April, 1919, the Truck Division believed that the standardization of wheel hubs for motor-trucks should be taken up for the benefit of truck operators by making possible interchangeability of wheels in emergencies, and permitting a reduction in the variety of axle bearings and hub dimensions, and for the benefit of the parts makers. A general questionnaire was sent out by the Society. The Wood Wheel Manufacturers Association and the Automotive Metal Wheel Association have cooperated very effectively with the Society throughout this program of standardization. A cooperative committee comprising representatives of the axle manufacturers prepared a tentative proposal which was submitted to axle bearing and vehicle manufacturers for comment. This proposal included five sizes of motor-truck front-axle spindles with their bearings and hubs laid out in considerable detail. The proposal, modified somewhat by reason of comments received, was reviewed at a meeting of axle manufac-

turers and changed slightly, after which it was considered by the Truck Division, and a report presented to the Standards Committee Meeting last January. After extensive and detailed discussion of the proposal, it was returned to the Truck Division for further consideration in accordance with the discussion at the Standards Committee Meeting. The Truck Division held a meeting immediately thereafter, at which a program was decided upon, and a resolution passed and published in THE JOURNAL to the effect that the Truck Division would reconsider the proposal, and desired further information in this connection from the industries.

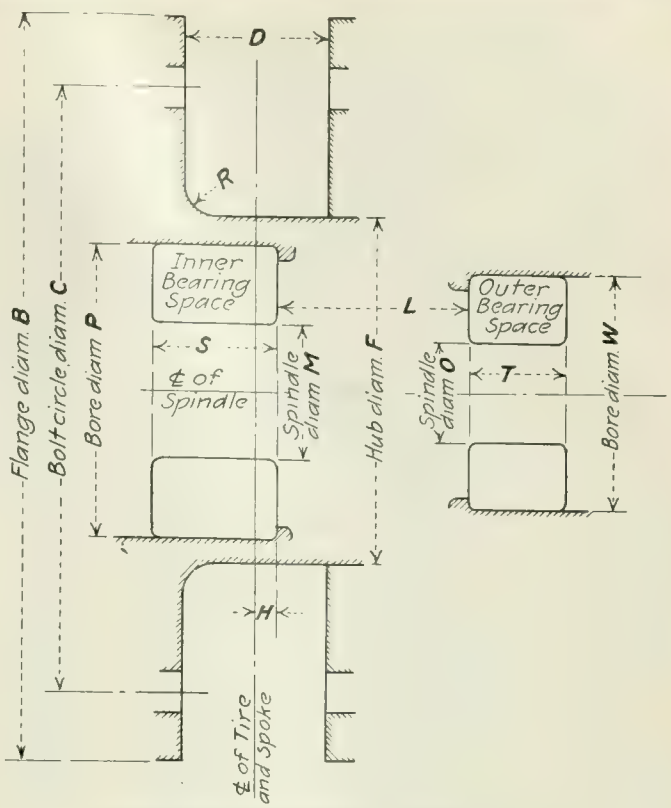
A meeting was called on March 3 in Detroit, which was attended by representatives of parts and vehicle manufacturers interested in this program. The proposal up to this time had included dimensions for inch-size roller-bearing installation only, but it was strongly believed that provision should be made in a standard for ball bearings also. A committee was thereupon appointed, the members of which were representative of the bearing manufacturers, with the understanding that if it was found feasible to incorporate dimensions for ball bearings in the proposed standard, definite recommendations would accordingly be submitted by the committee. This committee met in Cleveland on April 4, and submitted its recommendation that provision be made in the proposed standard for definite ball bearing sizes of suitable capacities for the proposed series of hubs, these ball bearings being interchangeable with the present corresponding S.A.E. Standard metric roller bearing sizes.

A meeting of the original committee appointed by the wheel manufacturers was held in New York City on April 19 at which the recommended proposal was reviewed in some detail before the whole matter was finally considered by the Truck Division. The Truck Division held its meeting in New York City on April 21, a number of representatives of the vehicle, axle, bearing, and wheel interests being present. The whole proposal as presented to the Truck Division included two series of spindle sizes with their related parts in considerable detail. After thorough discussion of this proposal, it was deemed best to limit the proposed standard to only such dimensions as are essential for the interchangeability of bearings and wheels on the proposed series of spindles.

The Truck Division's recommendation of the dimensions shown in the accompanying drawing and tables was then submitted to the Standards Committee and approved for adoption as S.A.E. Recommended Practice.

TABLE 6—DIMENSIONS FOR INCH SIZE TAPER ROLLER BEARING HUBS

	Letter	Hub and Spindle Number R5	R6	R7	R8	R9
Diameter of flange	B	9	9 3/4	10 1/2	10 3/4	11 3/4
Flange fillet radius	R	1/2	1/2	3/4	3/4	3/4
Diameter of bolt circle	C	7 1/4	8	8 3/4	9 1/4	10 1/4
Number of flange bolts	..	12	12	12	12	12
Diameter of flange bolts	..	1/2	1/2	1/2	5/8	5/8
Spoke thickness between flanges	D	1 3/4	2	2 1/4	2 1/2	2 3/4
Hub diameter for wheel bore	F	4.1250 / 4.1280	4.6250 / 4.6280	5.1250 / 5.1290	5.5630 / 5.5670	5.9380 / 5.9430
Inner edge of inner bearing to centerline of spoke	H	1/4	0	7/16	7/16	11/16
Inner bearing shoulder to outer bearing shoulder	L	2 1/4	2 7/8	2 5/8	3 1/2	3 1/2
Spindle diameter at inner bearing	M	1.7495 / 1.7485	1.9995 / 1.9985	2.1245 / 2.1235	2.4995 / 2.4985	2.5620 / 2.5610
Spindle diameter at outer bearing	O	1.1870 / 1.1860	1.4995 / 1.4985	1.7495 / 1.7485	1.9995 / 1.9985	1.9995 / 1.9985
Hub bore for inner bearing	P	3.4820 / 3.4810	3.9810 / 3.9790	4.3720 / 4.3700	4.7310 / 4.7290	5.1840 / 5.1820
Hub bore for outer bearing	W	2.8570 / 2.8560	3.1540 / 3.1530	3.4820 / 3.4810	3.9810 / 3.9790	3.9810 / 3.9790
Overall length of inner bearing	S	1.5000	1.5000	1.5000	1.7500	2.1250
Overall length of outer bearing	T	1.1875	1.1563	1.5000	1.5000	1.5000



MOTOR-TRUCK FRONT-WHEEL HUB DIMENSIONS

TABLE 7—DIMENSIONS FOR BALL BEARING OR METRIC ROLLER BEARING HUBS

	Letter	Hub and Spindle Number B5	B6	B7	B8	B9
Diameter of flange	B	9	9 3/4	10 1/2	11 1/4	12 1/4
Flange fillet radius	R	1/2	1/2	3/4	3/4	3/4
Diameter of bolt circle	C	7 1/4	8	8 3/4	9 1/4	10 1/4
Number of flange bolts	..	12	12	12	12	12
Diameter of flange bolts	..	1/2	1/2	1/2	5/8	5/8
Spoke thickness between flanges	D	1 3/4	2	2 1/4	2 1/2	2 3/4
Hub diameter for wheel bore	F	4.6250 / 4.6280	5.0000 / 5.0030	5.5630 / 5.5670	5.9380 / 5.9430	6.3750 / 6.3800
Inner edge of inner bearing to centerline of spoke	H	5/16	1/4	7/8	13/16	7/8
Inner bearing shoulder to outer bearing shoulder	L	2 1/16	2 3/8	2 1/4	2 7/8	2 7/8
Length of ball bearing spacer	a	2 5/8	2 7/8	2 13/16	3 9/16	3 11/16
Spindle diameter at inner bearing	M	1.7703 / 1.7689	1.9671 / 1.9657	2.1640 / 2.1626	2.3608 / 2.3594	2.5577 / 2.5563
Spindle diameter at outer bearing	O	1.3766 / 1.3752	1.5734 / 1.5720	1.7703 / 1.7689	1.9671 / 1.9657	2.1640 / 2.1626
Hub bore for inner bearing	P	3.9362 / 3.9340	4.3299 / 4.3277	4.7236 / 4.7214	5.1173 / 5.1141	5.5110 / 5.5078
Hub bore for outer bearing	W	3.1488 / 3.1466	3.5425 / 3.5403	3.9362 / 3.9340	4.3299 / 4.3277	4.7236 / 4.7214
Overall length of inner bearing	S	1 9/16	1 3/4	1 15/16	2 1/8	2 5/16
Overall length of outer roller bearing[9]	T	1 3/8	1 7/16	1 9/16	1 3/4	1 15/16

[9]When a wide type outer hub ball bearing is used, the spacer length should be L + 1/8 in.

TABLE 8—INCH SIZE ROLLER BEARINGS

Spindle No.	Bock, Bower, Gilliam, Timken			Proposed Width	Manufacturers Number and Width of Bearings			
	Bearing	Bore	Outside Diameter		Bock	Bower	Gilliam	Timken
R 5	Inner	1.7500	3.4843	1.5000	(435-43) 1.5000	(435T) 1.5000	(435-4320) 1.5000	(435-4320) 1.5000
	Outer	1.1875	2.8593	1.1875	(3191-3110) 1.1875		(3191-312) 1.1875	(3191-3120) 1.1875
R 6	Inner	2.0000	3.9843	1.5000	(455-45) 1.5000	(455T) 1.5000	(455-4520) 1.5000	(4580-4520) 1.5000[11]
	Outer	1.5000	3.1562	1.1563	(3381-3310) 1.1875[10]		(3381-3320) 1.1563	(3381-3320) 1.1563
R 7	Inner	2.1250	4.3750	1.5000	(539-53) 1.5000	(539T) 1.5000	(539-532) 1.5000	(539E-532) 1.5000
	Outer	1.7500	3.4843	1.5000	(435-43) 1.5000	(435T) 1.5000	(435-4320) 1.5000	(435-4320) 1.5000
R 8	Inner	2.5000	4.7343	1.7500	(5564-5500) 1.7500	(5564T) 1.7500	(5564-553) 1.7500	(5584E-5520) 1.7500
	Outer	2.0000	3.9843	1.5000	(455-45) 1.5000	(455T) 1.5000	(455-4520) 1.5000	(4580-4520) 1.5000
R 9	Inner	2.5625	5.1875	2.1250	(63-6310) 2.1250			(6379-6321) 2.1250
	Outer	2.0000	3.9843	1.5000	(455-45) 1.5000	(455T) 1.5000	(455-4520) 1.5000	(4580-4520) 1.5000

All dimensions are in inches.
[10]Bock will decrease this width to 1.1563 in.
[11]New size bearing.

It is now proposed to continue this work to include a series of similar hub dimensions for passenger-car front-axle hubs and also, if feasible, for a complete line of rear-axle hubs for passenger cars and motor trucks.

The following reference tables of bearing sizes are printed with the approved report of the Truck Division as information in connection therewith but were not included in the report as submitted by the Division. The dimensions in Tables 6 and 7 of the Division's report refer to the hub and spindle diameters, while Tables 8 and 9 give the sizes of bearings which are applicable for each series of hubs and spindles.

TABLE 9—BALL BEARINGS AND METRIC ROLLER BEARINGS

Regular ball bearing installations are the Wide Type double-row inner and Medium Series (single-row) outer bearings.

Wide Type (double-row) outer ball bearing installations are considered special.

Spindle	Ball Bearings (S. A. E. Numbers)		Metric Roller Bearings[3] S. A. E. Numbers)	
	Inner	Outer	Inner	Outer
B 5	309	307	Rm 309	Rm 307
B 6	310	308	Rm 310	Rm 308
B 7	311	309	Rm 311	Rm 309
B 8	312	310	Rm 312	Rm 310
B 9	311	311	Rm 311	Rm 311

[3]For Medium Series single-row, see S. A. E. Handbook, Vol. I, page C 28; for Wide Type double-row see page C 31.
[4]S. A. E. Handbook, Vol. I, page C 44.

UNACCEPTED RECOMMENDATIONS

Isolated Electric Lighting Plant Division Report

Rating of Storage Batteries

The report of the Isolated Electric Lighting Plant Division on the subject of proposed revision of rating of storage batteries, which includes only that portion of the report which was approved, is printed on page 63 of this issue of THE JOURNAL. The following part, printed as Section 2 in the report of the Division is given below together with the discussion on the whole report. The changes desired by the lighting-plant manufacturers at the subsequent meeting of the Gas Engine and Farm Power Association are printed in italics and enclosed in brackets.

SECTION 2

Storage batteries for farm light and power purposes shall be rated in terms of the number of hours discharge capacity at a constant rate corresponding to 300 [*200*] watts, or fifteen [*ten*] 20-watt lamps.

In determining isolated electric light and powerplant battery ratings, manufacturers shall conform with the following conditions:

(1) The normal range of specific gravity which is recommended by the battery manufacturers for the batteries in service shall be used during tests.
(2) Battery ratings shall be established at an initial temperature of cells not to exceed 80 deg. fahr.
(3) The watts at which the rating of lead batteries is determined shall be based on a normal voltage of 2 volts per cell. The final voltage on continuous dis-

charge shall not be less than 1.75 volts per cell.

(4) The batteries to be tested shall not be charged more than 120 per cent (in ampere-hours) of the last previous discharge

(5) The resultant test shall indicate the number of hours of service lead-acid batteries will give when discharged at a constant rate corresponding to 300 [*200*] watts.

[*(6) At 200 watts, 32 volts, the constant discharge rate shall be 6.25 amp.*]

THE DISCUSSION

MR. KEILHOLTZ:—Two years ago, at the summer session at Ottawa Beach, the Society adopted the intermittent battery rating for farm lighting plants and since then there has been considerable discussion of the subject. The lighting plant manufacturers, who form a section of the Gas Engine and Farm Power Association, voted at their convention in Chicago last September to request the Society to change this intermittent rating to the 8-hr. rating. Since then, the Isolated Electric Lighting Plant Division of the Standards Committee has met and considered a new method of rating expressed in watt-hours or kilowatt-hours. At a later meeting it was decided to recommend a continuous-discharge rating corresponding to 300 watts. Then this proposal was referred to a meeting of the lighting plant manufacturers section of the Gas Engine and Farm Power Association, which requested that the 300-watt continuous-discharge rating be changed to 200 watts.

Now it is proposed to abandon the present standard intermittent battery-rating as stated in the first section of the report. In the second section the proposed new rating for batteries is given in terms of the number of hours discharge capacity at a constant rate corresponding to 300 watts, or equivalent to fifteen 20-watt lamps. This was to be determined in accordance with certain specifications which are listed in the report.

Five and a half years ago, when the Delco Light Co. was organized, and it was the first to make large quantities of unit lighting plants, there was no standardized method of rating batteries; so it adopted what has been since known as the intermittent battery rating. This was later adopted by the lighting plant manufacturers. Later on, however, they wished to change, and since then they have first desired one kind of a rating and then another.

The proposed rating is not as satisfactory for small batteries as for large batteries, while the present intermittent rating is fair to both large and small batteries. Another point is that the proposed rating is not altogether fair to thick-plate batteries. A thick-plate battery cannot discharge as quickly as a thin plate battery, and it needs a discharge rating over a long period of time, such as the 72-hr. rating that is now the S.A.E. standard. This proposed rating is not satisfactory to the Delco Light Co., and we cannot see our way clear to adopt it. In our opinion it is a rating that nobody will use if it should be adopted, and I move that the intermittent battery rating be continued until a more satisfactory method can be found.

CHAIRMAN BACHMAN:—You have heard the report as presented by Mr. Keilholtz. He has made a motion which is contrary to the recommendations of the Division. I do not like to refuse anybody the opportunity to make a motion, but it places the chair in a rather embarrassing position to have the motion made in that way at this time.

MR. KEILHOLTZ:—Would you prefer that I withdraw the motion for the present?

CHAIRMAN BACHMAN:—I would, as I think it would leave the matter in a somewhat clearer condition.

MR. KEILHOLTZ:—I withdraw the motion.

CHAIRMAN BACHMAN:—You have heard Mr. Keilholtz's presentation of the report and also his personal views on the subject. This whole question of the rating of batteries is a rather important one. It will be recalled that several years ago, when arrangements were made whereby the Society became the authorized body for conducting the standardizing activities and engineering functions of a certain group of commercial organizations, it assumed a considerable amount of responsibility, and is obligated to discharge that responsibility as well as possible.

The Society contributed to those gentlemen who came from the organizations referred to a large amount of experience in handling standards work and an organization which was competent to handle it; but so far as personal knowledge of the individual problems of the isolated electric lighting plant manufacturers is concerned, a great many of us are connected with an almost entirely different line of activity, which probably makes it somewhat difficult for us to translate our own experience into terms of their experience. Therefore, those of us who are building automobiles, trucks, airplanes or motorcycles may not have a fully sympathetic realization of the problems which these gentlemen have confronting them.

The present standard rating which is printed in the S.A.E. HANDBOOK was adopted after serious consideration, but has met with much opposition in many quarters. Any remarks that I may make are open to rebuttal, but I want to clarify the matter in your minds. It may be that much of the opposition is more of a commercial than an engineering nature, and perhaps we are facing a situation with regard to this subject similar to one we faced on another subject a few years ago at Ottawa Beach.

In the endeavor to satisfy the requirements of those opposed to the present standard, further rather extensive work has been done. There has been voluminous correspondence on the subject, a number of meetings have been held, and another proposal has been made. It is Mr. Keilholtz's opinion, and he is not entirely alone in his position, that the present rating does not meet all requirements. It is his opinion that the present standard is better than the one now proposed. Unfortunately, many of us who are not thoroughly familiar with the situation are sitting as judges.

With this brief outline of the situation, I will depart somewhat from our usual method of procedure and invite discussion before we have a motion.

C. T. KLUG:—From a battery manufacturer's standpoint, the 8-hr. rating is desirable; it is a rating that has been used for many years. As I understand it, the farm lighting plant manufacturers wish a rating expressed in terms of watts or watt-hours. In a comparative test of batteries it makes little difference what the discharge rating is inasmuch as every one should use the same rating. I suggest a 320-watt discharge rate as a compromise, which is equivalent to sixteen 20-watt lamps, and at the same time equivalent to a 10-amp. discharge rate. In discharging a storage battery the amperage could be held constant not by a certain number of 20-watt lamps but through some fixed resistance, and I think if rating in watts is wanted, 320 watts would be better than 300.

L. W. HEATH:—I was present at all of the Division meetings held to consider this farm-light battery-rating

matter. Mr. Keilholtz was not present at the last two meetings and we held the last meeting of the Division over an additional day so that he could attend. For the benefit of those here who are members of the Standards Committee and have to vote on this question, I want to say a few words on the situation, and I may express them somewhat differently than Mr. Keilholtz did.

In the first place, the present standard intermittent rating has been found unsatisfactory by nearly all makers of farm lighting powerplants, so much so that at a meeting of the farm-light-plant manufacturers held last fall in Chicago it was voted to ask the Society to cancel the present rating. The matter was then taken up by the Isolated Electric Lighting Plant Division, which has held two meetings since then. A number of methods of rating were suggested, and finally at the last meeting a vote was taken that the Division would agree on some one rating. Before adjourning, those present went on record as being in favor of the rating now proposed. This proposal was then referred to a meeting of the farm-light-plant manufacturers held shortly thereafter and it was agreed that the proposed rating was satisfactory, except that the rate of discharge should be changed from 300 to 200 watts. There was not time to have another meeting of the Division before this meeting of the Standards Committee. Others are here who were at the meetings referred to, and I think they will bear me out when I say that a great majority of the farm-light-plant manufacturers are opposed to the present intermittent rating and in favor of the rating recommended in the report, with 200 watts specified as mentioned.

MR. CHRYST:—I may have my own personal opinions on this question, but I want to speak now from the standpoint of the Standards Committee. I believe that the Society should not have any standards which are continually being changed and disagreed with. Inasmuch as this report is submitted in two sections, first, that the present rating should be cancelled and, second, that a new rating be adopted, I move that the Standards Committee approve the cancellation of the present rating and refer the whole subject back to the Division for further consideration and general agreement, inasmuch as the present rating is unsatisfactory and the Division itself does not seem to agree on the proposed new rating.

MR. KEILHOLTZ:—I believe that we should not continue a rating that is unsatisfactory to at least the majority, but I am sure that the proposed rating would not be satisfactory. I think that this subject should be referred back to the Division for further work until it can decide on some battery rating that the lighting-plant manufacturers will approve.

CHAIRMAN BACHMAN:—We may be getting into difficulty if we vote on the two sections of this subject at once. If we vote on one section at a time we will have a much clearer conception of what we are doing. Can we have the motion withdrawn and a motion made on each of the two sections?

MR. CHRYST:—I move that the first recommendation, Section 1, to cancel the present standard, be adopted.

CHAIRMAN BACHMAN:—It is clearly understood that Mr. Chryst's motion is to the effect that the report of the Division relative to the cancellation of the present standard be adopted.

[Mr. Chryst's motion was duly seconded and carried.]

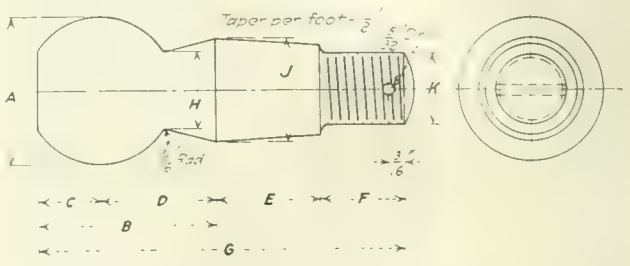
CHAIRMAN BACHMAN:—With regard to the second section of the Division's report, dealing with the proposed new rating at a 300-watt load changed to 200 watts, what is your pleasure?

MR. KEILHOLTZ:—I move that the Standards Committee do not approve the adoption of this Section 2, but refer it back to the Division.

[Mr. Keilholtz's motion was duly seconded and carried, there being one negative vote.]

Ball Studs

Early in 1920 the importance of standardizing ball studs was brought to the attention of the Society by parts manufacturers, who stated that ball studs are often more expensive than they would be if standardized, and that such a standard would be of value to manufacturers and users. The subject was assigned to the Miscellaneous Division and the data obtained by circularizing carefully reviewed. A recommendation was then formulated and circularized among motor-truck and axle manufacturers for comments which were carefully considered at a meeting of the Parts and Fittings Division to which the subject had been transferred. Several of the suggestions which had been received were incorporated in the recommendation of the Division as submitted for adoption as S.A.E. Recommended Practice and as given in the accompanying table.



No.	A	B	C	D	E	F	G	H	J	K
1	1	1 3/4	7/16	15/16	13/16	13/16	3	5/8	0.766	5/8-18
2	1 1/8	1 1/2	1/2	1	13/16	1 1/16	3 1/2	5/8	0.766	5/8-18
3	1 1/4	1 11/16	9/16	1 1/8	1	13/16	3 1/2	3/4	0.875	5/8-18
4	1 1/2	1 7/8	5/8	1 1/4	1 1/8	7/8	3 7/8	13/16	1.000	3/4-16
5	1 3/4	2 1/8	3/4	1 3/8	1 1/4	1	4 1/8	15/16	1.250	7/8-14

THE DISCUSSION

E. R. DOUGLAS:—The company I am connected with has not been able to do much in general manufacture of ball studs because there have been so many kinds and sizes. Every car builder has his own sizes. We are very glad indeed that standardization is being attempted and want to see the best results attained. There are a number of particulars in which the design of ball studs should be considered. It is a little part, but one of considerable importance. While in general this proposal is very good, there are some points and some dimensions which should be reconsidered. In one size, for example, the diameter at the neck does not allow for enough angular motion of the socket on the stud. The other sizes are very good in that respect.

The strength of the ball stud involves several things; it involves material, which of course the manufacturer must choose; it involves the length from the center of the ball to the large end of the taper where it fits into the forging, and the diameters of the stud at *H* and *J*. With relation to the strength, ball studs of different sizes should have linear dimensions theoretically in strict proportion. That cannot be adhered to closely in prac-

tice because we do not want to machine all of the dimensions to thousandths of an inch but we can keep to practical proportions by adhering to ordinary dimensions. That proportionality is departed from, in a number of dimensions applying to the studs proposed, in one case rather widely. In that instance the departure gives a considerably greater strength in proportion to the load, and causes difficulty due to angular motion and some possible interference.

Room should be allowed for the chasers which cut the thread to run out but do not believe that a neck should be placed in the ball stud to allow the thread to run out. Dimensions which are necessary for those chasers to run out and for the use of standard nuts on the studs should be specified. The dimension *F* certainly does not allow sufficient room for a castellated nut.

There are one or two other points in the proposal which should have more consideration, and we believe the report should be returned to the Division for further study.

MR. HORINE:—With regard to the dimension *A* which is given as 1, 1⅛, 1¼, 1½ and 1¾ in., the balls must fit into the sockets, which are machined out by reamers that happen to come in the sizes specified. The balls should be slightly undersized, as the reamer is the part which we have to buy, that is, the tool which establishes the socket into which this ball must fit. For example, I recommend that on the No. 4 size the ball be 1 31/64 instead of 1½ in. in diameter, that is, 1/64 in. under the reamer size. I also think that a radius of 1/16 in. between the ball and the neck, which is specified for all sizes of stud, is too small. That is the weakest point on the whole stud; on the larger sizes the 1/16-in. radius amounts to a real weakness. I suggest at least a 3/16-in. radius.

I believe that the length *E* is not great enough. It has been the experience of a number of manufacturers besides ourselves that studs fail because there is not sufficient length of taper. The 1½-in. taper has been tried and found less satisfactory than the 1¼-in.

I suggest that this whole subject of ball studs be referred back to the Division for further consideration.

MR. STRICKLAND:—The report was based on data received from axle manufacturers located all over the country, and provides a reduction in the number of sizes in use today. There are, however, a few points that might be cleared up, and I think the report should be returned to the Division.

ADDRESS OF CHAIRMAN BACHMAN

In closing the session of the Standards Committee, Chairman Bachman addressed the meeting substantially as follows and conducted a brief executive session to give the members of the committee an opportunity to make suggestions in connection with the conduct of the work and to propose any new subjects to which the committee should give consideration.

We have had a shorter period of time than usual between the Annual Meeting and this one, and we have a correspondingly longer period of time between this meeting and the next Annual Meeting.

The reports that have been submitted today are highly representative of the quality of the standards work, and each time that we come together and consider reports, we increase our responsibility and our ability to get results. There is no question that one of the greatest activities the Society has ever gone into is automotive engineering standardization. It has been one of the things that has brought the Society to the favorable attention of not only the executives of our industry but other engineering and commercial organizations. I had the pleasure last week of addressing a commercial organization in Philadelphia on the subject of standardization, and was surprised that such a topic should have had the reception it had, particularly in the way that I could present it, and among a group of salesmen.

Now, I do not mean that standards work is without criticism. We have had some of it here today in our own meeting, and all the criticism that we can get of a constructive nature that is listened to and taken in the spirit in which it is given, will make for better work.

We have about 7 months before us until our next meeting. Of that 7 months we have probably three in which under even normal circumstances we would not hold meetings very often and do much work. Under the present conditions, however, we probably will be able to do even less. The fact that we have had such a good meeting today is I think a promising sign that we realize the need of cooperation and of coordinated effort. While we may not be able to see each other or to meet in committee, there are several things that we should do.

The reports which have been passed here today will be considered by the Council and very briefly at the business session tonight. It is impossible, under present conditions, to give very lengthy attention to any of these matters at the business sessions as the time is not available, but the Society office will send letter ballots for final approval of these reports by Society members. We have a large membership, and in the past only about 12 per cent of the voting members have returned these letter ballots on the Standards Committee reports. There is not a man in this room or a man in the Society who is competent to pass on every one of the subjects that is brought up in the Standards Committee, but a large majority are directly concerned in what the Standards Committee does in at least one or two matters which you and your friends know something about. Every voting member of the Society should return his letter ballot.

You who are members of the Standards Committee should constitute yourselves missionaries to see that those who are not directly connected with Standards Committee work give some attention to it, because only insofar as it is representative of the combined activity and thought of the members of the Society is it worth anything. If we do not get the benefit of such thoughtful cooperation it simply means that subjects come up, are reported and passed, that are deficient in one way or another, even with the consideration that we do give them. These deficiencies will eventually be published in the S. A. E. HANDBOOK and either be followed with disastrous results in one way or another, or detract from the reputation which we have to sustain.

The members of the several Divisions should take a direct personal interest in the work of their Divisions. Do not think that the chairman is the only one having any responsibility. Each member has been appointed by the Council, has accepted the appointment and has a direct responsibility to the Society as a whole and to the industry in general. Become familiar with the topics that have been brought up for discussion by the Division and give some constructive thought to them. Not every member can attend every Division meeting, but every one can give consideration to the subjects that are before the Division and submit his opinions in some definite form.

Finally, I want to touch on the question of having these matters properly circulated among those who are interested. We have an organization at New York City whose function and responsibility is to see that this is done. You cannot do it; I cannot do it; we are not supposed to, and the Council doesn't ask us to. It

does ask this office organization to do it, but it is very discouraging to prepare and send out inquiries and get very few acknowledgments and very little needed information. That is all I wish to say, but I believe it will be profitable for all of us to bear in mind t he necessity for helpful cooperation in this work in the future. If there are subjects which you think the Standards Committee or any of its Divisions should consider, send advices as to them to the Society so they may be properly assigned to a Division and work started in accordance with regular methods of procedure.

Attendance at Meeting

The members of the Standards Committee and the Society and the guests in attendance were

Standards Committee Members

J. J. Aull
E. E. Bachman
David Beecroft
R. S. Begg
W. J. Belcher
C. C. Bowman
A. E. Brion
W. M. Britton
A. K. Brumbaugh
H. E. Brunner
T. V. Buckwalter
R. S. Burnett
E. J. Burrows
C. C. Carlton
Clarence Carson
D. E. Chambers
W. A. Chryst
C. F. Clarkson
W. F. Cole
J. R. Coleman
A. W. Copland
C. S. Dahlquist
G. W. Dunham
E. H. Ehrman
J. B. Fisher
L. C. Fuller
C. E. Godley
C. O. Gueinsey
F. W. Gurney
W. S. Haggott
L. W. Heath
M. C. Horine
E. A. Johnston
L. S. Kelly, Jr.
W. C. Keys
C. T. Klug
G. L. Lawton
B. M. Leece
A. D. T. Libbey
T. C. Menges
C. A. Michel
G. L. Miller
C. T. Myers
J. B. Nelson
I. M. Noble
H. S. Pierce
Gustof Peterson
F. R. Pleasonton
H. J. Porter
M. P. Rumley
C. E. Sargent
A. J. Scaife
A. W. Scarratt
C. W. Spicer
W. R. Strickland
J. G. Swem
G. J. Thomas
L. M. Wainwright
J. A. White
S. O. White
F. G. Whittington
Samuel Wilbur
Ernest Wooler
G. A. Young

S. A. E. Members and Guests

V. G. Apple
J. H. Baninger
R. C. Barron
G. M. Bartlett
Joseph Bijur
C. R. Bissell
W. J. Bryan
H. C. Buffington
W. T. Burns
O. E. Byron
Herbert Chase
H. E. Clay
E. O. Christiansen
K. H. Condit
L. R. Davis
E. Dicker
N. S. Diamant
G. P. Dorris
E. R. Douglas
F. G. Drisler
W. H. Fenley
H. G. Freeland
G. W. Gilmer, Jr.
H. A. Githens
G. O. Hanshew
J. N. Heald
P. M. Heldt
L. C. Hill
M. G. Hoffman
M. L. Hillmer
H. H. Hine
Russell Hoopes
H. W. Jarrow
Clyde Jennings
C. J. Kalbfell
L. M. Kantes
T. S. Kemble
W. H. Knowles
N. Lazarnick
W. E. Lay
R. G. McCaugha
John McGeorge
J. F. Marshall
J. A. Mower
R. E. Northway
Joseph Pihm
N. B. Pope
W. T. Raph
A. R. Reid
D. Roesch
O. J. Rohde
J. E. Schipper
E. H. Schwartz
C. F. Scott
F. A. Shuler
R. H. Soulis
C. R. Stough
A. L. Swank
W. S. Turner
A. S. VanHuffelen
R. F. Walters
J. A. White
C. P. Wilson
H. G. Wilson
C. W. Wolfe
H. T. Wreaks
C. W. Young

BRAKE-LINING TESTS

THE development of satisfactory commercial tests for brake-linings is one of the problems with which the automotive engineer has been contending without having found an entirely satisfactory solution. Tests have been devised that were founded more or less on the individual's ideas, but have been of no practical value or shown any uniformity of methods.

At the joint meeting of the Truck Division of the Standards Committee and the Truck Committee of the National Automobile Chamber of Commerce held on April 21, 1919, discussion of the advisability of establishing standard tests for tractive ability, torque, brake efficiency and similar factors led to a decision to develop suitable brake-lining wear and heat tests for adoption and use in the determination of brake-lining specifications and coefficients of friction. It was suggested at that time that the work should be conducted by the Society in a laboratory of its own but this was obviously not feasible. As the Motor Transport Corps contemplated establishing purchasing specifications for brake-linings, arrangements were made for the Motor Transport Corps to furnish the necessary apparatus and the Bureau of Standards to conduct the tests, the work to proceed under the general supervision of a subdivision of the Truck Division in cooperation with the Motor Transport Corps and the Bureau of Standards. A. K. Brumbaugh, Clarence Carson and H. C. Dickinson comprised the Subdivision and in order that the tests might be conducted as rapidly as possible, arrangements were also made with the Bureau of Standards whereby the Subdivision furnished one of the engineers to perform the tests at the Bureau of Standards.

With the reorganization of the Standards Committee for 1921 this work, which was formerly assigned to the Truck Division, was transferred to the new Parts and Fittings Division. The original Subdivision was enlarged by adding representatives of four additional brake-lining manufacturers. A meeting was held in New York City on April 19, 1921, at which the results of the work accomplished up to that time were discussed in detail and the decision reached that each of the brake-lining manufacturers represented on the Subdivision would construct testing equipment similar to that installed at the Bureau of Standards and conduct an independent series of tests. It was felt that this would be of material assistance and afford an opportunity to obtain much comparative information.

At a conference called at the Bureau of Standards on May 17 which was attended by representatives of practically all the brake-lining manufacturers, a report and analysis of the progress which had been made there was submitted and discussed. Many valuable data and much information had been obtained by the Bureau which indicated that the problem is much more complex than was anticipated. It was felt generally that the testing should be continued and another conference called after the Bureau and the several manufacturers shall have more nearly completed their investigations.

The lack of definite information and uniform practice with regard to the testing and operation of brake-linings clearly indicates that the establishment of standard tests which can be followed by manufacturers and users and form the basis for purchase specifications will be an important accomplishment in this branch of the industry. Such standards when carefully planned and executed should make possible greater uniformity of materials and establish a better understanding of the essentials involved.

PRODUCTION ENGINEERING

THE production engineer is the man responsible for planning the routing of work through the shop, the sequence of operations and the maintenance of a regular flow of material to each machine, insuring that when the parts arrive at the erecting floor, all the necessary material will be on hand in correct quantities. Under the old methods the responsibility for laying out the progress of work through the shop rested with the shop foreman. With very rare exceptions his method of scheduling the work was to wait until a man finished one job before deciding which of the jobs waiting to be done should be undertaken next. This involved consideration on the part of the foreman as to which of the available jobs suited the particular man's ability and which of the jobs should be given preference. Frequently the waiting workman would be kept idle until the foreman had decided these points. Even after some particular job had been decided upon, more time would be spent in a discussion as to how the job should be handled.

This is not a criticism of the foreman because of his lack of planning as his duties under the old method were numerous and left him no opportunity for planning in advance. He was required to pass judgment on different questions as they arose, and upon his ability to give a snap judgment depended the success or failure of the whole matter. In the majority of cases, the output under the circumstances was very creditable. Under present conditions, however, it is impossible for even the smallest shop to run to the best advantage without more planning of the work than has been usual in the past. Therefore, in every shop it is necessary for someone to perform the duties of a production engineer. If the plant is small, this man will be able to perform additional duties, but it is essential that the problem of routing jobs through the shop be given consideration.

Production Engineering for the Small Shop

The scheduling of work through a small shop presents in some ways more difficult problems than it does in the large shop, owing to the relatively greater variety of work handled and the fact that there is a smaller number of men and of machines to choose from. For these reasons, the ability of the available mechanics becomes the vital point for consideration in distributing the jobs. In such shops it is necessary that whoever handles the scheduling must have an intimate knowledge of the ability of the men who are to do the work. The conclusion is, then, that in the medium-sized or small factory it is seldom that any one except the foreman would have the knowledge necessary to schedule the work successfully, but when thus burdened with production work he should be relieved of enough of his other less important duties to enable him to devote the necessary time to planning the work.

In actual experience the output of a moderate-sized machine shop has been increased more than 50 per cent by merely having the various jobs carefully planned ahead, choosing that work for each man at which he was most proficient, and having the next job with all essential information waiting at his machine before he had finished the previous job. In larger plants where a production engineer is employed, the work is scheduled to go to the machine that is most efficient for the particular job, and the foreman is responsible for obtaining the most suitable operator for the machine.

Method of Routing and Scheduling the Work

The end toward which the production engineer should work is to have every operation on every piece of work that is passing through the shop scheduled definitely and clearly both in regard to the machine which is to be employed and the time that it is to be performed; at least, the order in which the jobs are to be executed should be specified. The most desirable sequence of operations will usually be decided upon, and then, after estimating the time requirement for each operation, it is possible to distribute the work to the best advantage among the available machines so as to avoid overtaxing any of them. The best plan is to have the work arranged so that all of the machines will be kept busy all of the time.

The division of the work among the various machines demands careful consideration, especially when dies or special tools are required for executing the work. The reason for this is that generally, after the tools are made, it is difficult and expensive to transfer the work to another machine if it is found that the one chosen has been assigned more work than it can do according to schedule. The jobs should be run through in as large lots as possible to avoid changing tools too often, although some leeway must be had here, because if the lots are too large some unforeseen delay may prevent the delivery to the erecting gang of some essential part and thus stop work on the erecting floor. At the same time, this trouble is less likely to occur even with poor scheduling than it is with none at all.

It is surprising how many supposedly up-to-date plants are running the work through the shop with practically no planning, the infallible result being that some of the machines are loaded with a quantity of work beyond any possible output that can be expected of them, while other machines stand idle, thus seriously impeding the possible output of the plant. This condition usually results in a continuous rush to get out some part necessary to complete a job which may have been overlooked, and as a result the whole shop is thrown into a turmoil, trying to catch up with the erecting crew. To attempt to run any machine shop today without some kind of schedule is about as foolish as it would be to try to run a railroad without a time table. Furthermore, to wait until a man finishes one job before deciding on the next is on a par with a railroad on which the train crew has to stop at each station to find out at what place they stop next, if such a foolish thing can be imagined.

There are numerous reasons for employing engineering methods in directing the flow of production through the shop. While at first sight the labor and expense involved in maintaining a schedule may seem formidable, this is really not the case, since the economies that will be effected both in reduced costs and in an increased output will return a big dividend on the expenditure. It is not necessary that the work, to pay for scheduling, be repetition work, for it has been my experience that it pays as well to schedule the work through a repair shop as through a manufacturing plant. The schedule for a repair shop must naturally be more elastic than it is in the manufacturing plant to allow for the occasional breakdown job which must be handled at once, but even then the schedule has its advantages in that it gives a better idea of the situation and shows which work can be laid aside to take care of the emergency job. It may seem on first thought that the breakdown of a machine would throw the whole schedule out of order, but this is not true, as with the information that was used in making the schedule it is possible to rearrange it by transferring the work to some other machine, or find out just what it is possible to do at short notice more readily and surely than can be done without this information. The schedule also shows the amount of time that may be consumed in repairing the machine without holding up production.

Assigning Jobs for Maximum Production

It is common knowledge to those who have worked in the shop that a man will finish a job more quickly when he knows that the next one is waiting for him than he will when he does not know what he is to do next. This fact is especially noticeable when there happens to be a disagreeable job waiting to be performed that no one wants and every one tries to avoid until it has been assigned. Many machine operators make a habit of lagging in their work at the end of a job, thinking that it is entirely up to the foreman to keep them

busy, and as long as they can make an appearance of being at work they will not tell the foreman that they are ready for another job. Some will absolutely refuse to report when through with a job, but depend upon the foreman to know and to assign the next job when he gets around to deciding what it is to be.

This leaves all the responsibility of knowing just when each job is completed to the foreman. If a number of men finish their jobs at the same time, which often happens, a serious loss of time is incurred until the foreman can decide upon the next job for each, one after the other, and give each his instructions. Under these circumstances an error in judgment on the part of the foreman in distributing the work or in issuing instructions is very likely to occur. On the other hand, if a schedule were arranged, the foreman could distribute the work among the men without waiting for the completion of the various jobs.

The importance of and the knowledge required for production engineering cannot be over-emphasized. It demands a thorough knowledge of all machines, machining operations and time required to perform the work, as well as good judgment regarding general shop practice. The successful production engineer will not stop at the scheduling of the work, but will be able to assist the designing engineer in developing designs which can be most economically manufactured with the available equipment, thus avoiding the buying of new machines that cannot be kept in operation.—J. S. Watts in *Machinery*.

SPORTS CONTESTS AT THE SUMMER MEETING

THE customary track and field events that add to the interest of each Summer Meeting were held, under the direction of the Sports Committee, on the athletic field adjoining the hotel. All of the events were hotly contested and the winners deserved the useful and valuable prizes that rewarded their efforts.

The following summary, which was crowded out of the June issue of THE JOURNAL, lists the events and also includes the names of the prize winners:

50-yd. Dash, men under 30—first, K. M. Lane; second, E. O. Jones; third, L. H. Gaylord
50-yd. Dash, men 30 to 40—first, L. E. Joseph; second, Neil McMillan, Jr.; third, V. E. Clark
50-yd. Dash, men over 40—first, Max Tost; second, E. H. Schwartz; third, George J. Thomas
Fat Men's Race, 200 lb.—first, L. H. Gaylord; second, G. A. Sanford
Ladies Potato Race—first, Mrs. E. Dickey; second, Mrs. C. M. Day
Ladies Egg Race—first, Mrs. C. M. Day; second, Mrs. G. A. Kraus
Ladies 50-yd. Dash, under 25—first, Miss Ruth Porter; second, Miss Loretta Van Aman
Ladies 50-yd. Dash, over 25—first, Mrs. E. Dickey; second, Mrs. G. A. Kraus; third, Mrs. C. M. Day
Ladies Baseball Throwing—first, Miss Norma Porter; second, Miss Ruth Porter
Ladies Walking Race—first, Mrs. H. L. Horning; second, Mrs. G. A. Kraus
Men's Walking Race, under 35—first, Gordon Brown; second, S. E. Bates; third, H. M. Benstead
Men's Walking Race, over 35—first, V. E. Clark; second, David Beecroft; third, B. J. Lemon
Three-Legged Race—first, Neil McMillan, Jr. and K. M. Lane; second, E. O. Jones and L. P. Jones; third, L. H. Gaylord and W. F. Rockwell
Intersectional Relay Race—first, Detroit, B. W. Brodt, V. E. Clark, E. O. Jones, L. P. Jones.
Intersectional Relay Potato Race—first, Indiana, Mark Smith, captain
High Jump, men under 30—first, B. W. Brodt; second, K. M. Lane; third, M. P. Whitney
High Jump, men over 30—first, W. F. Rockwell; second, S. E. Bates; third, Charles Wolfe
Shot Put—first, H. E. Kirby; second, L. H. Gaylord; third, Gordon Brown
Standing Broad Jump, men under 30—first, M. P. Whitney; second, Gordon Brown; third, J. E. Padgett
Standing Broad Jump, men over 30—first, L. E. Joseph; second, F. S. Whittington; third, W. F. Rockwell
Running Broad Jump, men under 30—first, B. W. Brodt; second, M. P. Whitney; third, Gordon Brown.
Running Broad Jump, men over 30—first, F. S. Whittington; second, L. E. Joseph; third, C. W. Wolfe
Hop, Skip and Jump—first, B. W. Brodt; second, L. E. Joseph; third, J. G. Vincent; fourth, David Beecroft

In addition to the members of the Sports Committee, under the able leadership of its chairman, Howard A. Coffin, the following assisted in making the field day a success: B. G. Koether, head judge of track events; Mark Smith, head judge of field events; J. J. O'Neill, C. R. Bissel, clerks of the course, and C. B. Veal, starter.

IRON AND STEEL DIVISION MEETING

A WELL attended meeting of the Iron and Steel Division was held June 20 and 21 at the Society office. In the course of the meeting a conference was had with representatives of the Metallurgical Committee of the American Gear Manufacturers Association and action taken to add to the S. A. E. Standard Steels two additional types of steel intended primarily for gears.

W. C. Peterson, chairman of the Subdivision on Sheet Steel, submitted a report of progress which indicated a desire for cooperation on the part of the sheet steel manufacturers.

C. N. Dawe, chairman of the Subdivision on Specifications for Cast-Iron Valve-Heads, submitted a report, accepted as final, which indicated that it is practically impossible to develop a satisfactory specification of this kind at present.

R. M. Bird, chairman of the Subdivision on the Effect of Size on the Physical Properties of Steel, submitted a progress report including blueprints showing the results obtained with a limited variety of compositions.

The Division spent an entire day on the revision of the Notes and Instructions for the steel specifications that has been under way for the past year. Much progress was made. It is planned to hold another meeting of the Division at Niagara Falls during the week beginning July 24 to complete this work at that time if possible.

THE DAYTON AERONAUTIC MEETING

THE joint aeronautic meeting of the Society and the American Society of Mechanical Engineers, which was held at Dayton, Ohio, on May 21, proved most interesting. There were 200 members of the two societies in attendance and all joined in praising the Air Service staff at McCook Field for its success in arranging a program so diversified and complete. Fortunately weather conditions were ideal for flying and this enabled the pilots to demonstrate their individual skill as well as the flying qualities of the many airplane types that were ground-inspected by the visitors.

Upon arrival at the field the members were received by Major Thurman H. Bane, commanding officer and genial host, who conducted a tour of inspection through the laboratories and shops. The materials-testing, powerplant, wind-tunnel, propeller and armament laboratories were visited. Some 25 types of airplane engine were exhibited including several foreign models. The special equipment used in testing carbureters was demonstrated and the propeller dynamometer was shown in operation. Great interest was shown in the airplane-armament exhibit; several types of machine gun and cannon were fired from stands and also through a moving propeller by synchronizer control. Different forms of ammunition were used and the purpose of each demonstrated by firing into airplane tanks filled with gasoline.

After completing the tour of the shops, the members inspected the fleet of airplanes assembled on the flying field for the purpose. Opportunity is seldom offered for the study of so many different airplane types in one group, ranging from the large Caproni and Martin bombing planes to the little single-seater Messenger airplane. A representative lot of the war-time airplanes of German, French and British origin was displayed, as well as some of the more recent designs. The McCook Field pilots completed the field program with a thrilling display of stunting and aero-acrobatics. The members were very much amused by the uncanny antics of the small wireless controlled electric automobile which went through all manner of evolutions at the command of its operator who was stationed 75 yd. distant.

In the afternoon a series of 10-min. talks was given by members of the McCook Field engineering staff. E. H. Dix, Jr., described some of the development accomplished at the Field in aluminum-silicon alloys for air-cooled cylinder castings. The advantages of air-cooled aviation engines and the advances being made in their design were enumerated by S. D. Heron. A comparison between airplane and automobile radiators was made by Lieut. Bayard Johnson, who also described the core constructions commonly used. C. F. Taylor discussed the characteristics demanded of a carbureter for airplane engines and the means generally adopted to secure them. The interesting subject of airplane camouflage was covered briefly by G. P. Young who showed designs which render invisible above 10,000 ft. planes which otherwise could not fly under 17,000 ft. without being detected. The progress in wireless telephony and the perfection of the wireless direction-finder were outlined by O. E. Marvel who emphasized the important function of wireless apparatus in the commercial operation of air carriers. The most fascinating talk of the afternoon was that of Capt. G. W. Stevens on aerial photography. He illustrated various types of ingenious equipment devised during and since the war for taking successive interlapping exposures and constructing extremely accurate maps from them. It was surprising to learn how exactly a section of country can be reproduced and at a cost far less than that involved in the customary land-survey method. The impression was left by Captain Stevens that this development constitutes a most important commercial application of the airplane. H. O. Russell concluded the program with a description of the types of synchronizing mechanism used to control gunfire through propellers.

A dinner was given for the visitors by the Dayton Section of the Society at the Engineers Club in the evening. J. H. Hunt was toastmaster at this very enjoyable affair and introduced as speakers C. F. Kettering, J. A. Steinmetz and F. Handley-Page of England. They talked primarily of aviation of course but the members were equally interested in the keen wit of Messrs. Handley-Page and Kettering. The dinner was followed by a military ball given by the officers of McCook Field. This provided an opportunity for the Dayton ladies to entertain the visiting members, which they did admirably.

Thanks are due Major Bane and his fellow officers for their efforts in arranging the excellent program at McCook Field and to the Dayton Section of the Society for the very fine dinner. We know that the visit to Dayton was appreciated by all who made it and will not soon be forgotten.

RECENT COUNCIL MEETINGS

SESSIONS of the Council held at West Baden, Ind., on May 24, during the time of the Summer Meeting of the Society were attended by President Beecroft, Vice-Presidents Horning, Bachman, Crane, Johnston and Menges, Past-President Vincent and Councilors Germane, Pope and Scarratt.

One hundred and forty-three applications for individual membership, three for affiliate membership and three for student enrollment were approved. The following transfers in grade of membership were approved: Associate to Service Member, R. O. Eliason; Junior to Member, Charles Hollerith; Associate to Member, Robert W. Davis, William J. Foster, T. F. Cullen, P. C. Cloyd; Member to Service Member, W. B. Elston. One action taken which it seemed necessary to take, much to the regret of the Council, was to strike from the roster of the Society the names of 110 members who had not paid the dues for the fiscal year beginning Oct. 1, 1919.

It was reported that the National Automobile Chamber of Commerce had voted to continue its annual appropriation of $7,500 to the standardization and research work of the Society.

The following Standards Committee appointments were made, with assignment as indicated:

L. W. Close—Ball and Roller Bearings Division
J. B. Fisher—Chairman Engine Division
R. J. Broege—Vice-Chairman Engine Division
Louis Schwitzer—Engine Division
W. E. Perdew—Lubricants Division
Herschell G. Smith—Lubricants Division
J. R. Coleman—Parts and Fittings Division
W. E. Holland—Vice-Chairman Storage Battery Division
Albert R. Reid—Storage Battery Division
John Mainland—Vice-Chairman Tractor Division

The Standards Department was authorized to prepare a skeleton Division organization in connection with nomenclature work.

The following additional subjects were assigned for study by the Standards Committee: Truck Division, Dumping Hoist Platforms and Body Hold-Down Clamps; Screw-Thread Division, Taper Tools and Products; Tractor Division, Formula for Stability of Tractors.

E. A. Johnston, chairman, C. B. Rose, A. H. Gilbert, G. A. Young, R. O. Hendrickson and John Mainland, were named as a committee to cooperate with committees of the National Implement and Vehicle Association and the American Society of Agricultural Engineers in the formulation of agricultural equipment standards.

The change of the name of the Boston Section to New England Section was authorized.

A session of the Council was held at the offices of the Society on June 23.

ACTIVITIES OF THE SECTIONS

ONE of the most important events of the Summer Meeting was the Sections Luncheon held on Tuesday May 26 this being attended by members of the Council, officers of the Sections and members of the Sections Committee. Plans were discussed for improving the work of the Sections and very valuable suggestions were received.

President Beecroft called upon H. R. Corse, chairman of the Sections Committee, to outline the suggestions of that committee. The committee recommended that the program committee of each Section prepare within the next few weeks a tentative schedule of meetings, giving the proposed subject and author for each meeting during the coming year, and send this program to the office of the Society at New York for *suggested* additions or variations. The Committee believes that papers should be prepared sufficiently far in advance to enable them to be preprinted when desirable and sent to the Section members prior to the meetings at which they are to be presented. The discussion should under these circumstances be of much greater value.

R. E. Northway, past-chairman of the Boston Section, spoke of the desire of that Section to change its name to "New England" and the necessary change in the Section By-Laws was thereupon approved by the Council, a meeting of which was immediately called for that purpose.

H. W. Slauson, chairman, Metropolitan Section, agreed that the full season's program should be laid out in advance and promised that a list of subjects with hoped-for speakers could be obtained by early July. H. L. Horning told of the Mid-West Section's plans for the coming year which involve a series of lectures on thermodynamics, the principles of carburetion and combustion phenomena. The meetings will probably be held at Lewis or Armour Institute where physical laboratory apparatus is available. He spoke of the important work being done at Dayton on elimination of knock and said that vaporization of fuel is the most important problem today.

Lon R. Smith, chairman, Indiana Section, thought it desirable to coordinate the work of the different Sections to avoid duplication. Some members were of the opinion that repetition of a paper at more than one Section meeting is beneficial since added discussion results from such a plan. Dr. H. C. Dickinson, chairman, Washington Section, said that a number of meetings of a semi-popular nature had been held at Washington but that the program for this season would probably be of a more technical nature. T. F. Cullen, secretary, Pennsylvania Section, considered it possible to formulate plans for the season's work by July. He was interested in the proposed Aberdeen Proving Ground meeting. G. T. Briggs, vice-chairman, Mid-West Section, believed it advisable to hold inexpensive dinners in connection with the Section meetings and spoke of the success of the last Mid-West meeting at which the price of the dinner was $1.

Past-President Vincent urged that an aeronautic meeting be held by some Section in connection with a meeting of the Council. He spoke of the current popular misapprehension in regard to aeronautic affairs and thought that this could be dissipated by proper discussion in all Sections; the technical nature of the papers to vary according to the character of the audience which might be expected at different places. In connection with possible subjects for marine engineering papers, he suggested clutches and reverse gears and lubricating systems with reference to cooling the oil. B. B. Bachman, in speaking of Herbert Chase's paper on clutches, cited it as an example of what a paper of that type should contain. He suggested rear axles as a subject which could be similarly treated. He mentioned the possibility of the refinement of design in most parts of a car and the advisability of papers thereon, based upon a knowledge of past weaknesses and successes.

H. M. Crane urged that papers be prepared thoroughly, giving real facts and not be merely unimportant rambling discourses. He suggested lubricating systems and steering-gears as two subjects which might prove desirable for attention at Section meetings. L. S. Keilholtz said that the problems encountered in the design of isolated electric plants are numerous and not the same as those affecting car engines. He thought that a paper should be prepared in this connection. A. W. Scarratt, past-chairman, Minneapolis Section, talked on the impossibility of differentiating fuel and lubricating oil values from refiners' claims and said that experimentation must be conducted by machine manufacturers to enable the user to be informed as to the best grades to use. He urged that the tractor be adapted to industry as well as to the farm.

E. A. Johnston approved of the course of the Mid-West Section in its plans for the coming year. In suggesting subjects for meetings he spoke of the difficulty of uniform distribution of kerosene to all cylinders, the gas-producer with charcoal, and a comparison of steam and gas tractor efficiencies at various loads. J. H. Hunt, vice-chairman, Dayton Section, was confident that the program for the ensuing year could be laid out early in July except for those meetings which are to be held in conjunction with the Dayton Engineer's Club. T. C. Menges, vice-president of the Society, believed that more time could be given advantageously to stationary engines.

C. F. Scott, chairman of the Society Meetings Committee, stated that Section papers should not be secondary to those presented at Society meetings as to either subject or treatment. Good papers covering subjects adequately are necessary and if such papers are given, the attendance will take care of itself in Mr. Scott's opinion. He further believes that our engineering outlook should be years ahead instead of months.

A. K. Brumbaugh, past-chairman, Pennsylvania Section, said that in Philadelphia it is advisable to have semi-technical meetings because of the diversity of interest in that city. George E. Goddard, vice-chairman, Detroit Section, gave a number of specific suggestions for papers, including the design of pistons, methods of surfacing cylinder walls, and the insurance problem.

A number of other suggestions indicating the views of members as to specific subjects for Section papers are being received and further comment from members of the Society will be gladly considered.

Those who attended the luncheon were:

B. B. Bachman
David Beecroft
Geo. T. Briggs
Horace A. Brown, Jr.
A. K. Brumbaugh
R. S. Burnett
C. F. Clarkson
Hugh R. Corse
H. M. Crane
T. F. Cullen
Dr. H. C. Dickinson
G. W. Gilmer, Jr.
G. E. Goddard
L. C. Hill
K. K. Hoagg
H. L. Horning
J. H. Hunt
A. E. Jackman
E. A. Johnston
L. S. Keilholtz
C. D. LeFevre
H. G. McComb
T. C. Menges
James A. Moyer
R. E. Northway
B. S. Pfeiffer
A. W. Scarratt
C. F. Scott
H. W. Slauson
Lon R. Smith
C. B. Veal
J. G. Vincent

Applicants *Qualified*

The following applicants have qualified for admission to the Society between May 10 and June 10, 1921. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

ARGEEN, JAMES S. (A) service manager, Northway Motors Corporation, *Boston*, (mail) 120 Peterboro Street.

ARMINGTON, A. P. (M) superintendent and tractor engineer, Euclid Crane & Hoist Co., *Euclid, Ohio*.

BASKERVILLE, DEAN E. (M) automotive body engineer, Dodge Bros., *Detroit*, (mail) 1455 Field Avenue.

BEST, NORMAN A. (M) engineer, metal division, Dow Chemical Co., *Midland, Mich.*, (mail) 717 Midland Avenue.

BOURNE, PHILLIPS P. (M) chief engineer, Blake Knowles works, Worthington Pump & Machinery Corporation, 265 Third Street, *East Cambridge, Mass.*

BOYD, FRANK M. (A) general manager, secretary and treasurer, Motor Parts Corporation, 1419 North Charles Street, *Baltimore*.

BRADY, L. J. (A) assistant manager, Nash Sales Co., 2000 South Michigan Avenue, *Chicago*.

BROWN, GORDON (M) engineer, Condensite Co. of America, *Bloomfield, N. J.*, (mail) 79 North Mountain Avenue.

BULLOCK, HOWARD F. (A) district representative, United Motors Service, Inc., *Detroit*, (mail) 11-104 General Motors Building.

CASTRICONE, JOHN A. (M) factory superintendent, Pittsburgh Model Engine Co., *Pittsburgh*, (mail) 537 Turrett Street, East End.

COBB, E. E. (A) manager of sales and service, United States Malleable Iron Co., *Toledo*.

COLLINS, ALFRED S. (A) electrician, Franklin Repair & Service Co., *Brooklyn, N. Y.*, (mail) 236 Decatur Street.

DAVIS, STUART B. (J) engine design layout draftsman, Haynes Automobile Co., *Kokomo, Ind.* (mail) 1015 South Indiana Avenue.

DE WITT, L. W. (A) sales agent, National Malleable Castings Co., Cleveland, (mail) 1636 Dime Savings Bank Building, *Detroit*.

DIFFENDAUGH, HARRY (S M), *Camp Devens, Mass.*

EDGERTON, LEWIS S. (E S) student, Massachusetts Institute of Technology, Cambridge, Mass., (mail) 455 South Fourth Street, *Fulton, N. Y.*

EVELYN, STEVEN F. (M) designing engineer, Continental Motor Corporation, *Detroit*

FARR, HENRY W. (A) sales manager, Johnson Co., 1909 Forest Avenue, East, *Detroit*

FAUST, WALTER L. (E S) 812 Hudson Street, *Hoboken, N. J.*

FOSKETT, MAYNARD L. (J) chief engineer, Charleston Motor Car Co., *Charleston, W. Va.*, (mail) 508 Randolph Street.

GALLAGHER, FRANK J. (A) assistant to city fire marshal, *Philadelphia*, (mail) 6101 Columbia Avenue.

GASTINEAU, G. A. (M) manager of technical division, Hupp Motor Car Corporation, *Detroit*, (mail) 921 Iroquois Avenue.

HATHORN, CHARLES E. (A) designer, Curtiss Aeroplane & Motor Corporation, Garden City, N. Y., (mail) 22 Lafayette Avenue, *Hempstead, N. Y.*

HENDRY, M. JAMES (A) sales engineer, Agni Motor Fuel Co., *Chicago*, (mail) 2042 Seminary Avenue.

HUBBARD, HENRY M. (A) automotive designer, Cleveland Ordnance Engineering Office, *Cleveland*, (mail) Suite 18, 2035 East 96th Street.

JOHNSON, ARTHUR E. (J) draftsman, Holt Mfg. Co., *Stockton, Cal.*, (mail) 529 East Minor Avenue.

KAZEY, ARTHUR R. (M) assistant chief engineer, Ross Gear & Tool Co., *Lafayette, Ind.*, (mail) 806 Cincinnati Street.

KEEL, CHARLES H. (M) patent law, 15 Park Row, *New York City*.

KEISLER, SCOTT W. (A) salesman, Otwell Mower Co., *Detroit*, (mail) 62 West Alexandrine Avenue.

KLOCK, FRANKLIN GRASHOFF (J) engineer, lubricating department, Sinclair Refining Co., *Chicago*, (mail) 1614 Byron Street.

LINEK, JOSEPH, JR. (J) foreman, J. Linek, *Maspeth, N. Y.*, (mail) 5 Elm Street.

MCMAHON, JAMES J. (J) in charge of engineering, Mercury Motors Corporation, 5929 Baum Boulevard, *Pittsburgh*.

MANNIEN, ARVO (E S) 110 Sixth Street, South, *Virginia, Minn.*

MATSON, HUGO WILFRED (E S) automobile repair student, Virginia Vocational High School, *Virginia, Minn.*, (mail) 221 Second Street, North.

MIGUELON, P. E. (A) branch manager, 2000 Wabash Avenue, *Chicago*.

OLLEY, MAURICE (M) engineer, Rolls-Royce of America, Inc., *Springfield, Mass.*, (mail) 46 Rockland Street.

OUTCALT, WILLIAM J. (J) head of standard parts department, General Motors Corporation, *Detroit*, (mail) 6003 McClellan Avenue.

PATTEN, RAYMOND E. (J) custom body designer, Hume Body Corporation, Boston, (mail) 90 Naples Road, *Brookline, Mass.*

POTTER, ALBERT T. (M) chief engineer, Ainsworth Mfg. Co., *Detroit*, (mail) 2906 Whitney Avenue.

RUNCIMAN, H. D. (A) secretary, Hoover Steel Ball Co., *Ann Arbor, Mich.*

SAKS, IRA (A) secretary, treasurer and sales manager, Pennsylvania Piston Ring Co., *Cleveland*, (mail) 829 East Boulevard.

SAUER, HERBERT F. (A) manager Cleveland branch, Electric Storage Battery Co., 2325 Chester Avenue, *Cleveland*.

SHIDLE, NORMAN G. (A) editorial staff *Automotive Industries*, Class Journal Co., *New York City*, (mail) 880 West 180th Street.

SORENSON, CLARENCE S. (J) mechanical engineer, C. M. Gay & Son, *Los Angeles, Cal.*, (mail) 1651 West Jefferson Street.

SUDDUTH, ARTHUR L. (J) instructor, School of Automotive Electricity, *Milwaukee*, (mail) Third Apartment, 163 Mason Street.

THOMS, LOUIS (M) engineer, truck division, Advance-Rumely Co., *Battle Creek, Mich.*

VICKERS, HARRY F. (J) engineer, Arthur L. Eaton, 3769 Moneta Avenue, *Los Angeles, Cal.*

WALKER, GILBERT DUNSTAN (M) production manager and engineer, Nofalt Motor Products Co., Inc., Holyoke, Mass., (mail) 14 Charter Oak Avenue, *Hartford, Conn.*

WALTON, GEORGE (A) general sales manager, Self-Seating Valve Co., 340 West Huron Street, *Chicago*.

WARNER, FRANCIS J. (A) district engineer, Standard Oil Co., Spokane, Wash., (mail) P. O. Box 2156.

WEINERT, RICHARD H. (M) efficiency engineer, Studebaker Corporation, Detroit, (mail) 26 Sturtevant Avenue, *Highland Park, Mich.*

WEINSTEIN, HARRY (E S) student, Pratt Institute, *Brooklyn, N. Y.*, (mail) 1764 Bergen Street.

WITTE, OTTO A. (M) chief engineer, American Bureau of Engineering, Inc., 1603 South Michigan Avenue, *Chicago*.

WITTER, HARRY L. (A) lubrication engineer, Standard Oil Co., *Detroit*, (mail) 2688 Columbus Avenue.

WOOD, JAMES E. (A) district sales manager, Roller-Smith Co., of New York, 7016 Euclid Avenue, Cleveland.

WRIGHT, LAWSON W. (A) president, Western Radiator Corporation, 410 North Western Avenue, *Chicago*.

YOUNG, LINWOOD H. (A) president, Linwood H. Young Co., 701 Beacon Street, *Boston*.

Applicants *for* Membership

The applications for membership received between May 26 and June 22, 1921, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ALLAN, ROBERT K., chief draftsman, Shefko Ball Bearing Co., Ltd., *Luton, Bedfordshire, England.*

ANDERSON, RALPH W., student, Buffalo Technical High School, *Buffalo.*

ARROW, PERCY JOHN, inspecting engineer and salesman, Associated Equipment Co., Ltd., *Walthamstow, London.*

ASIRE, HORACE W., research engineer, General Motors Research Corporation, *Dayton, Ohio.*

AUMENT, H. CHESTER, manager of parts department, Locomobile Co., *Bridgeport, Conn.*

BANCROFT, FLOYD C., technical field representative, Hare's Motors, Inc., *New York City*

BIRMINGHAM, C. J., service manager, Locomobile co., *Bridgeport, Conn*

BRADY, GROVER C., battery repairman, Thompson Auto Co., *Windsor, Ont., Canada*

BRUNELL, HOMER A., garage owner, B. & H. Garage, *Los Angeles, Cal*

CARLE, A. E., engineer, American Bronze Corporation, *Berwyn, Pa.*

CARMAN, ARTHUR G., chemist and metallurgist, Franklin Die-Casting Corporation, *Syracuse, N. Y.*

CHERRY, GEORGE H., sales engineer, American Bosch Magneto Corporation, *Detroit.*

CLARK, RALPH R., student, Michigan Agricultural College, *East Lansing, Mich*

COLBURN, HERBERT C., mechanical engineer, *Stockton, Cal.*

COLE, CECIL W., student, Tri-State College of Engineering, *Angola, Ind.*

COLVILLE, CHARLES J., general manager, Parenti Motors Corporation, *Buffalo.*

DAMES, GUST A., mechanical engineer, 335 West 51st Street, *New York City.*

DEAN, C. W., mechanical and electrical engineer, Dean Engineering Co., *Norfolk, Va.*

DOE, THOMAS B., vice-president and general manager, U. S. Cartridge Co., *Lowell, Mass.*

DOTEN, EVERETT F., mechanical engineer, Muskegon Motor Specialties Co., *Muskegon, Mich.*

DUFFECK, FRANK W., general manager, Electric Power Maintenance Co., *Toledo.*

EDWARDS, WILLIAM H., research department, American Telephone & Telegraph Co., *New York City.*

FAGAN, XEN, general manager, Diamond branch of Rome Wire Co., *Buffalo.*

FALE, WILLIAM M., assistant chief engineer, Continental Motors Corporation, *Detroit.*

FISCHBECK, HENRY J., heat-treatment foreman, Wright Aeronautical Corporation, *Paterson, N. J.*

GEARHART, MAJOR GUY L., engineering division, Air Service, McCook Field, *Dayton, Ohio*

GUELET, IRVING J., designer, Osgood Bradley Car Co., *Worcester, Mass.*

HARRISON, JACK, service superintendent, Packard Motor Car Co. of Boston, *Providence, R. I.*

HOWARD, THOMAS, executive chairman, National Institute of Inventors, *New York City.*

HUTCHINSON, ROLAND V., mechanical engineer, General Motors Research Corporation, *Dayton, Ohio.*

JARROW, HARRY W., Western manager, American Felt Co., *Chicago.*

KING, ALEXANDER H., mechanical engineer, Automarine Plane & Motor Car Co., *New York City.*

KIRKPATRICK, WILLIAM J., assistant service manager, A. Schrader's Son, Inc., *Brooklyn, N. Y.*

KOCHER, EDWARD H., manufacturing engineer, Bijur Motor Appliance Co., *Hoboken, N. J.*

LANE, F. VAN Z., general maintenance manager, Hare's Motors, Inc., *New York City.*

LAVERY, LORNE FLETCHER, engineering draftsman, New Departure Mfg. Co., *Detroit.*

LEE, GEORGE H., automotive instructor, United States Army, Fort Jay, *Governors Island, N. Y.*

MACNAB, F. B., business manager, General Motors Research Corporation, *Dayton, Ohio.*

MARSHALL, J. F., territory manager, American Felt Co., *Chicago.*

MEESON, WILLIAM P., works manager, Arrol-Johnston, Ltd., *Dumfries, Scotland.*

MEYER, F. H., sales manager, Cleveland Welding & Mfg. Co., *Cleveland.*

MITCHELL, C. F., assistant professor of mechanical engineering, University of Wisconsin, *Madison, Wis.*

MONTANYE, JAMES, technical supervisor, General Motors, Ltd., *London, S. W.*

MOSS, J. W. S., manufacturing engineer, Ever-Tyte piston ring division, Walter A. Zelnicker Supply Co., *St. Louis.*

ORTEIO, JULES P., president, Orteio Motor Co., *New York City.*

PARKS, CHARLES, president and sales manager, Parks-Campbell-Finley Motor Co., *Oklahoma City, Okla.*

PARSONS, J. B., engineer, Prest-O-Lite Co. of Canada, Ltd., *Toronto, Canada.*

PETERSON, W. G., metallurgist, Atlas Crucible Steel Co., *Detroit.*

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Research in the Automotive Industry

By Dr. H. C. Dickinson[1]

THE Research Committee and the Council have much satisfaction in announcing that Dr. H. C. Dickinson, known to the members as a result of his conspicuous work at the National Bureau of Standards and in basically helpful cooperation with the automotive industry, will have immediate charge of the Research Department of the Society. Dr. Dickinson is relinquishing service with the Government in devotion to the purposes and tenets underlying the decision that the Society shall proceed in an organized way to further cooperation and coordination in research fundamentally requisite in the solution of the more immediate engineering problems confronting the members as a whole.

Nature, complex in gross, hides her secrets from untrained reason. Experiment, a sort of cross-questioning, separates out a particular group of facts, examines them alone and makes possible answers showing the rationality of things. Dr. Dickinson analyzes herewith in a preliminary statement the methods that are to be followed in and what can be expected from the momentous step being taken by the Society.

BEFORE discussing the subject of research, it is important to agree upon the meaning of the term. Research, as the term is used here, means merely a diligent search for information. Such information may come from the literature or from experiment and observation. Thus, research may be classed, for convenience, under three heads: (*a*) explorational, (*b*) intensive and (*c*) developmental.

Explorational research is usually preliminary in character. It deals with the fundamental analysis of problems through the study of available literature and of the technical and economic conditions involved. It serves to direct intensive research and development along desirable lines.

Intensive research includes the major part of the work usually accomplished in experimental research laboratories. It generally requires considerable laboratory equipment and the results should serve to supply the mass of detailed technical information necessary for industrial progress and development.

Developmental research cannot always be readily differentiated from the more common process of development by trial and error. The mere trial of one expedient after another in an attempt to solve a technical problem without an analysis of the requirements of the problem and of the causes of failure of the various expedients, can hardly be classed as research. This is the method of evolution, as well as that by which practically all the mechanical arts have received their initial development. It seldom leads to the highest efficiency and never to a knowledge of principles. Properly developmental research involves the application of experimental facts and principles to the solution of practical problems.

Need of Research

The automotive industry has attained its present position and magnitude through a development involving, among other things, a large measure of good fortune. An important factor has been the relatively easy and rapid interchange of ideas among members of the industry, together with the opportunity of giving practical expression to new ideas in the form of new models of vehicles. This has led to a rapid process of evolution in which the "survival of the fittest" has promptly elim-

[1] M.S.A.E.—Manager, research department, Society of Automotive Engineers, New York City.

inated those ideas that had not reached a practical commercial stage, rather than those that were unsound in principle. There is reason to believe that this evolutionary process can no longer go on at the same rate as in the past. It is an expensive process at best, and, perhaps responsible for some of the present depression in the industry. On the other hand, it would be a fatal mistake to retard progress in development, and more efficient means of progress are needed. Such means are to be found in a more general application of analytical methods in development. For instance, such problems as the overall cost of truck transportation, involving both the cost of vehicles and the cost of roads, cannot be solved correctly without a careful preliminary study of the various factors involved and of their relative importance as regards the general economics of the problem. The truck builder cannot safely design and market vehicles that will increase unduly the cost of roads, nor can the road engineer afford to design roads that limit unduly the hauling capacity.

In the matter of fuels, there are essential relations between the quality of fuels that can be produced and the design of engines that will use these fuels economically. The adaptation of one to the other has in the past lagged far behind the changing fuel-quality, with consequent fuel waste. There are also necessary relations between cost of the fuel, tires, repairs, and the like, and the number and weight of vehicles that can be maintained in service throughout the country. Changes in any of the items of cost demand changes in the design of the vehicles.

Explorational research should point the way in which progress should be directed. With this information at hand the designer will immediately require the best information as to how to modify designs in accordance with the probable future demand; in other words, apply the results of intensive research in development.

Opportunities of the Society

While the need of fundamental research is perhaps no greater in the automotive industry than elsewhere, the Society of Automotive Engineers is in the enviable position of being one of the youngest and largest of the engineering societies. Its membership is made up in great part of young men who are accustomed to cooperate in an industry in which change is the order of the day. There could hardly be a more favorable field for the organization of a systematic research program such as the Society has decided to undertake; nor has any other industry better facilities in men and equipment for the prosecution of such a program.

Research Facilities

Facilities for research include both personnel and material equipment. While the latter is much more readily classified and therefore constitutes the major exhibit in lists of available facilities, the former is by all means the more important factor from the point of view of research accomplishment. Research men, like artists, are born, not made, although their abilities must be developed through instruction and experience. This refers not so much to research-laboratory assistants, so to speak, who may be able to carry out the details of experiment or run tests, but rather to those men who must be looked to for all analytical thought and constructive ideas that research develops. Such men are rare and can do their best work only under favorable conditions. The success of any research depends primarily on the *interest* of the investigator. For this reason research men cannot be instructed as to what problems they shall undertake, except within very wide limits. The term "direction of research" is a misnomer. Research can be guided but hardly directed.

Research institutions may be divided into three general classes: (*a*) Industrial laboratories, connected with and supported by individual firms or corporations; (*b*) educational laboratories connected with colleges, universities and technical schools; and (*c*) independent research laboratories such as those of the Government and a few endowed institutions whose chief aim is research rather than instruction. Each of these three classes of laboratory has advantages and disadvantages, and each should be in a position to supplement the others in the development of any general research program.

The industrial laboratories are primarily supported directly or indirectly by the profits on the results they obtain. This being the case, they are usually subjected to insistent demands for the completion of any work in hand to a point that will permit its prompt commercialization. On the other hand, they have the advantage of the closest possible contact with the requirements of the industry in their particular line. While the demand for prompt results may make for increased productivity, it is almost fatal to the prosecution of comprehensive researches to a final satisfactory conclusion. These conditions are favorable to developmental research but distinctly unfavorable to explorational and intensive research, since even very important and valuable results are likely to fail of final verification or not reach the stage of publication for lack of time. Another handicap that should be removed from many industrial laboratories is that of secrecy. Since the results of development must often be held in confidence, this does not apply to fundamental facts that result from explorational and intensive research. A free interchange of such facts is absolutely essential to any constructive research development.

There are many industrial laboratories at the present time that have excellent material facilities and able men who are doing little that can be classed properly as research. They are purely development laboratories. The possibilities of these laboratories should be realized to much greater extent.

Educational Laboratories

The chief object of educational institutions is necessarily the instruction and training of students. This function cannot be neglected if the industries are to have trained technical men available. In most cases, therefore, the research laboratory must have for its prime object the training of men rather than the securing of results. Unfortunately, in most cases the professors who might carry on important independent researches, if time were available, are too fully occupied with their official duties as teachers to permit more than supervision of the work of students. In a meager number of cases research fellowships enable educational institutions to retain the services of a few men whose time can be devoted mainly or entirely to research; but in most cases these men expect to remain not more than a year or two. Only a limited class of research problems can be undertaken successfully by students, or temporary research fellows, viz., problems of such a nature that they can be completed in comparatively brief periods by men of relatively immature experience. In most cases the laboratories are not in as close contact with the requirements

of the industry as might be desired; the problems are necessarily selected more often for their suitability in the instruction of students than for their importance to the industry.

The chief needs of the educational laboratories seem to be a closer contact with the problems and requirements of the industries, such assistance as can be given in the way of securing the selection of problems of greater importance and a more general recognition on the part of our educational institutions that high-grade men with time to accomplish important researches on their own account can alone supply to the students that inspiration without which research training is almost useless.

Independent Laboratories

The independent laboratories are represented mainly by those of the Government. Their main financial support does not come directly from the commercialization of their results. Hence they are not hampered as are the commercial laboratories by demands for immediate results. When equipped with adequate facilities it is possible for these laboratories to undertake fundamental problems requiring more continuity of time and more equipment than are available in most educational laboratories, and problems of a more fundamental character than most industrial laboratories will undertake, because such problems are considered less fruitful in immediate commercial results. These laboratories have, however, the disadvantage of inadequate contact with the industries and may not appreciate the relative importance of their various problems. The independent laboratories cover a field not occupied by either of the other classes of institution.

Utilization of Existing Facilities

In theory the various laboratories and individual investigators should be occupied with the kinds of problem with which each is best fitted to deal. This would mean a minimum of duplication of effort and each man working at a suitable task. Unfortunately, this is an ideal utterly impossible of attainment, and a serious attempt to attain it would wreck any research program at the beginning.

Much has been said of late about duplication of effort in various lines, particularly in research. Although unnecessary duplication may be inexcusable in general, some duplication in research is both necessary and unavoidable and should be utilized, rather than prevented, but excessive and ill-considered duplication should of course be prevented. It is necessary because no fundamental research is or should be accepted at its face value until the results have been checked and rechecked by independent observers. It is unavoidable because research men do effective work only on problems in which they are vitally interested, and several are usually interested in the same problems. Moreover, the competitive element between different men and institutions when properly controlled is one of the greatest inducements to thorough and accurate work. This requires a free and adequate interchange of information between men and institutions. Such interchange of ideas can be depended upon largely to prevent unwise duplication and leave in the field only those most likely to succeed.

All men and institutions are, however, interested in lines of work which promise results of value, and the selection of the most promising lines of intensive research depends upon an adequate survey of the field, i. e., upon explorational research, the importance of which seems not to have been fully appreciated.

The aims of the Research Department of the Society for the immediate future are to encourage and secure so far as possible a more systematic survey of the research field as applied to our industry, to bring to the attention of the various laboratories such problems as appear in most pressing need of solution or of increased attention, and to secure to the greatest extent feasible a more general interchange of information between the various laboratories and individual investigators.

In attempting to develop such a system of interchange of information a sharp line of distinction is recognized between development or developmental research and fundamental or intensive research. The former must be considered of a private and confidential nature, while the latter is distinctly of more value if mutually shared by all members of the industry.

The Society bespeaks the hearty assistance and cooperation of all laboratories in securing a wider distribution of those results which are of general value to the automotive industry.

REINSTATEMENT OF 1919-1920 DELINQUENT MEMBERS

As announced in The Journal for July, the Council directed at its May meeting that the names of over 100 members should be stricken from the rolls of the Society for non-payment of dues for the fiscal year beginning Oct. 1, 1919.

Paragraph 16 of the By-Laws provides in part that a person dropped for non-payment of dues must, if desirous of again joining the Society, first pay the dues in arrears at the time of being dropped, and may then make a new application for membership, and further that the Council may in its discretion restore to membership any person whose membership has ceased for any cause, upon such terms and conditions as it may at the time deem best for the interest of the Society.

At the meeting of the Council held in June, applications for reinstatement were received from several of those who had ceased to be members of the Society by the action of the Council in May as stated above. In the case of those who in conformity with the provisions of the By-Laws mentioned above, sent remittances for the dues in arrears at the time they were dropped, the Council voted to grant reinstatement without the payment of an additional initiation fee, this action being taken in view of current industrial conditions. The instances in which the Council has waived payment of another initiation fee by those wishing to rejoin the Society are few in number and there have been no such cases until within the last few months when it was felt that unusual conditions required special action.

It being clear, however, that it is necessary that there be some time limit beyond which the Council will not grant reinstatement under the conditions set forth above, without payment of another initiation fee, a resolution was passed that Sept. 1 next should be set as a limiting date, with the direction that due notice to this effect be given in The Journal.

JUNE COUNCIL MEETING

THE meeting of the Council held on June 23 was attended by President Beecroft, Vice-Presidents Bachman and Crane, Councilor Pope, Treasurer Whittelsey, Chairman Scott of the Meetings Committee and Chairman Copland of the Transmission Division.

The Treasurer's report showed that the unexpended income of the Society for the first eight months of the current fiscal year was $6,377.16, the income for the period having been $165,940.21. The expense was $50,436.95 less than originally contemplated by the budget. The total assets of the Society on May 31 were $190,627.35, with accounts payable of $10,824.82.

Some interesting figures were presented with regard to the attendance at the Semi-Annual Meeting of the Society held at West Baden, Ind. in May. The total number present was 698, there being 114 ladies in the party and all of the men present except 52 being members of or applicants for membership in the Society. It is somewhat remarkable and also significant that there were more members at West Baden than at any previous Summer Meeting of the Society, with the exception of that held at Dayton in 1918 which was a meeting of rather abnormal size owing to war conditions, 649 members and 351 guests being in attendance. The attendance at the meetings held at Ottawa Beach in 1919 and 1920 totalled 634 and 816 respectively. There were 346 members present at the Ottawa Beach sessions in 1919, and 471 in 1920.

The applications for membership that were ready for consideration by the Council were submitted and 72 applications for individual membership and 2 for student enrollment approved. The following transfers were made in grade of membership: Associate to Member, J. A. Edwards, W. F. Barrett; Junior to Member, Z. C. Bradford, Milton Evans Chandler, Otto L. Formigle, Ford L. Prescott, Joseph Rawley, Samuel E. Rowe, J. A. Thompson, B. Russell Shaw; Member to Foreign Member, J. F. Engberg.

It was reported that 414 applications for membership had been received during the first five months of this calendar year, as compared with 578 during the same months of 1920.

The following appointments to the Standards Committee were made with assignment as indicated:

P. J. Dasey—Engine Division
George L. Bixby—Storage Battery Division and Electric Vehicle Division
George S. Cawthorne—Truck Division
R. C. Schell—Passenger Car Division
L. A. Chaminade—Passenger Car Division

Ralph Murphy was designated as Chairman of the Passenger Car Division.

In connection with the Sectional Committee of the American Engineering Standards Committee being formed to draft an aeronautical safety code, V. E. Clark, H. M. Crane, G. C. Loening, R. H. Upson and I. M. Uppercu were designated as representatives of the Society.

In connection with the plea made by Mr. Goldbeck of the Bureau of Public Roads at the meeting of the Society held in May that a committee consisting of highway engineers and automotive engineers be formed, it appears that the most important feature of such a program is a fuller appreciation of the general problem of the economics of transportation, involving a proper balance between the cost of construction and maintenance of highways and the cost of construction, maintenance and operation of vehicles. Engineers associated with the highway departments of various States have made a rather careful study of the problems of road construction and maintenance. From the point of view of the automotive engineer the problems of the users of trucks are obviously important, since the pivotal point involved is that of the general economics of transportation rather than the technical problems of the design and construction of motor trucks. It is believed that a careful survey of the whole general problem of costs of truck transportation should be made and a projected program for the next year or two be decided upon with a view to showing clearly the estimated relative importance of the various technical matters requiring investigation.

INSPECTION OF ABERDEEN PROVING GROUND

MILITARY preparedness consists not in maintaining a vast accumulation of costly military stores, munitions and fighting apparatus which in most cases become worthless through obsolescence; nor does it require the establishment of a considerable standing army of fighting men. It is vitally necessary, however, that each person shall know how he may be of most use to the country in war time. His usefulness will depend upon his understanding of military requirements and this ability to assist in the working out of such problems as may be encountered. The more knowledge he has of these matters before the outbreak of war, the less time will it take for him to get into action when the need arises.

Considering the importance of motor transportation in war, the automotive engineer has his field definitely laid out in advance. He must design, build, operate and repair the motorized equipment. To do these things intelligently he must be in close touch with the developments and experiments of the War Department.

Major-General C. C. Williams, chief of Ordnance, United States Army has extended an invitation to the members of the Society to visit Aberdeen Proving Ground, Maryland, on Friday, Oct. 7. Included in the invitation also are members of other engineering societies interested in ordnance developments. The Army Ordnance Association will, in addition, hold its annual convention at Aberdeen on the same day.

The Aberdeen Proving Ground is, in the opinion of ordnance experts, the most complete establishment of its kind in the world. Tests are made there not only of guns, ammunition and armor-plate, but also of aircraft and automotive equipment. During the war a complete plant for the manufacture of gas and the loading of gas shells was constructed and put into operation at Aberdeen.

The Pennsylvania, Metropolitan and Washington Sections will visit Aberdeen on Oct. 7 in lieu of their October meetings, and it is expected that the attendance will include many members from more distant points than the headquarters of these sections.

Aberdeen Proving Ground is located a short distance north of Baltimore, somewhat off the line of the Pennsylvania Railroad. Special Army trains are run, however, connecting the Proving Ground with the Aberdeen railroad station.

Full particulars regarding train schedules and a detailed program of the exhibits to be scheduled and tests to be made will be given later.

Fundamental Points of Carbureter Action

By F. C. Mock[1]

Buffalo Section Paper *Illustrated with* Drawings and Charts

IT is always difficult to determine exactly, and define accurately, the actions that enter into the functioning of a carbureter because these are so intimately interconnected with many others equally complex and equally vital, all uniting in the operation of the modern internal-combustion engine. In carbureter work one must hold fast to an absolute faith in physical science and the immutability of Nature's laws; many things seem to happen that we can reject, at the time, only because we know they cannot be and yet we must be always alert to find the errors of our previous conceptions and ready to accept the existence of forces and phenomena that were not known before. We must steer a mean course between the attitude of the unskilled service man, who believes that the carbureter, if properly built, can compensate for all deficiencies in the 600-lb. mass of metal beside it under the hood, and that of the theorist, who would plan it all out on paper without soiling his hands in experimental tests.

As the subject of carbureter action is broad, it seemed possible in such a paper as this only to select and set forth some of the main laws and basic considerations that apparently exist and which we use as guides in the engineering work of our own organization. I believe that an understanding of these laws will be of great assistance to all automotive engineers, particularly those engaged in engine and motor-car development.

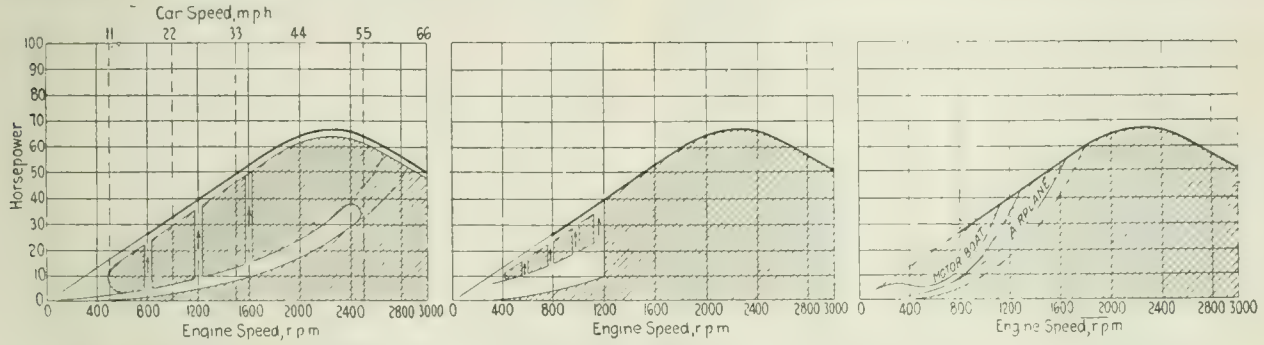

Fig. 1—Average Power Operation of a Passenger-Car Engine, a Truck or Tractor Engine and Airplane and Motorboat Engines

Carbureter versus Fuel Injection

Before proceeding further with the subject I want to justify the effort thus involved by making a brief defense of the carbureter as a means of supplying fuel to an engine, particularly as compared with the fuel-injection method. In the modern carbureter, which if my memory is correct has been cruelly characterized by a fuel-injection advocate as an "uncertain and complicated device suitable only for laboratory use," rotation of the engine draws in the air, the inflow of air draws its charge of gasoline in a fixed proportion and the engine cannot rotate without getting its predetermined mixture proportion. Further, the mixture is *stable* under changes of load and speed, a point that we appreciate only after trying other methods of fuel feed; for instance, a gravity, needle controlled, flow of gasoline into the mouth of an upturned intake-pipe.

In the carbureter the fuel is fed as a steady stream through a metering orifice and the effect of surface tension becomes negligible. For fuel injection each charge must be an individual minute drop or globule. Under the range of temperatures encountered the change in metering due to change of capillarity and viscosity will be very high and as soon as the walls of the injection duct get hot the globule, with the range of fuel volatility we have to handle today, will tend to disintegrate due to the boiling of its light elements.

Furthermore, the present motor-car fuel system operates on a range of quantity of mixture, from light load low speed to high speed full load, of over 30 to 1, and goes smoothly and positively from any one point in the range to any other. The very essence of the usefulness of the motor car and motor truck lies in this flexibility, in traffic service, under adverse road conditions and the like. The tractor and the airplane were satisfactory at first with a limited speed-range and little flexibility, but as they have developed much greater flexibility has been demanded. Is there a small high-speed multi-cylinder fuel-injection engine in existence today that has a speed and load range of 3 to 1 and will make the change smoothly and without danger of stalling?

With the modern type of carbureter there is very little trouble due to wear, deterioration or change of the instrument in service. We know now that most of the difficulties formerly charged up to the carbureter were due to the non-volatility of the fuel and could be overcome only by changes in other parts than the carbureter.

The fuel situation has been steadily changing in the last 7 years. In each engine-building department of our large factories the value of the production equipment is hundreds of thousands of dollars. Is it not sane economics to do as much as possible in adaptation to the

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changing fuel situation with a small easily modified device such as the carbureter, rather than worry along under continuous and uncertain, but always costly, modifications in engine design? If we can make the car operate better by introducing new elements into the carbureter and these elements are positive and permanent in their operation, is there any reason whatsoever why this should not be done? In fact, there are some carbureters in use today whose construction is not complicated enough. If the characteristic of a given type of carbureter is such, for instance, as to give an unduly rich mixture in certain parts of the average driving range, or if some other equally important defect is present, we can say, I think, that the design of this carbureter is not complete until these faults have been remedied.

Conditions in Cylinder, Manifold and Carbureter During Normal Operation

The first thing necessary in a consideration of this subject is a clear and definite understanding of the conditions existing in the carbureter and the intake-manifold. As every carbureter man knows to his sorrow, the ordinary dynamometer "horsepower curve" is not at all representative of general engine performance. The engine can operate at all speeds between idle and full load; that is, the total range of performance possible, if the conditions of operation permit, can be designated by the area between the power curve and its baseline. Very often, however, the conditions of operation are confined, more or less definitely, to portions only of this area. I have endeavored to show these limitations by the curves of Fig. 1. A more intelligent representation might be obtained perhaps with curves showing the torque at different speeds.

The specific conditions of engine performance will be considered in more complete detail in later portions of this paper relating to mixture requirements. It is sufficient to point out here that for passenger cars the full power of the engine is seldom used at ordinary speeds, but is used very often at low engine speeds because only small throttle-openings will give full torque at this time. As we all know, the full power of the engine at high speeds is used very seldom indeed. The motor truck and the tractor have considerably less range of action than the passenger-car engines, while motorboat and airplane engines, working under propeller load, are very definitely limited as to range of torque and speed.

We all understand how at wide-open throttle the rate of mixture delivery from the carbureter depends upon the engine speed and the volumetric efficiency. At part throttle and part load, however, these relations are less clear, the quantity of mixture passed being governed partly by the throttle position and partly by the engine speed. It is very important that we understand the conditions existing in the intake-manifold of these different throttle positions, loads and speeds, as well as under changes from one condition to another.

Relation of Throttle Position, Manifold Vacuum and Engine Torque

The throttle, I might point out, is not necessarily a part of the carbureter, although usually so considered. There are some who think of the throttle as controlling the volume of air fed to the cylinders; instead, the volume of charge per cylinder is constant and the power of the engine is regulated by the change of the mixture density in this fixed and continuous volume of cylinder charge. Now, if we select any engine speed and vary the throttle position under changing load with the correct mixture proportion, we find that the charge density in the manifold, as shown by barometer readings, bears a definite relation to the torque developed; also that this relation is almost identical for all engine speeds. Fig. 2 contains a set of curves illustrating this, and Fig. 3 gives a general average of the results of our record tests. We believe that the curving over of the lines of Fig. 2 is an indication of the intake-valve restriction and that it is possible to determine the valve limitations by this method of analysis.

The maximum torque is usually obtained at not over 1½ in. of vacuum. This cannot be given as an exact figure because the vacuum registered is partially due to air velocity and partially to kinetic energy losses, and for other reasons, but 1½ in. is a fair average for all speeds with engines of four or more cylinders on one manifold. One of the reasons for not securing an air charge at atmospheric density, or 100 per cent volumetric efficiency, is the expansion of the air charge when it enters the hot combustion-chamber. It is obvious that under such conditions a slight initial rarefaction of the air charge, as expressed by this 1½ in. of mercury vacuum will have little or no effect upon the charge density at the end of the intake stroke.

The developed torque decreases with an increasing vacuum or a decreasing barometer down to zero with the engine idling at about 18-in. vacuum. It is very difficult to find what charge density corresponds with zero indicated torque and we can only guess at these points, with the volume of exhaust residue as a guide. For any given cylinder temperature and compression ratio it should be possible to construct a line such as that dotted on Fig. 3, by which the density of air charge corresponding with any given torque can be estimated, according to the horizontal distance between the torque and zero consumption line. The space at the left of the zero consumption line represents the volume of exhaust residue in the cylinder at the beginning of the intake stroke.

The left portion of Fig. 4 shows the gain of torque with decreasing speed, for a given size of air-opening. The line *a* indicates the torque that would be obtained with a throttle-opening which would give a 16-in. vacuum at 1000 r.p.m. This is about the torque required to drive the average car on a not too smooth country road. If the road becomes rougher or a hill is encountered so that the speed of the engine is reduced to 800 r.p.m., this will decrease the air velocity through the throttle orifice, which will in turn reduce the manifold vacuum with an increase of about one-third in the torque as shown. A further increase of the load will slow down the engine and raise the torque still more, until, with this same throttle-opening, a full air-charge will be delivered to the engine, and full torque developed at about 130 r.p.m.

A similar condition exists with regard to the resistance of the entire carbureter at wide-open throttle and high speed. The lines *b* and *c* at the right of Fig. 4 show a comparison of the power developed by two carbureters, one of which, *b*, has 2 in. of mercury vacuum at 2400 r.p.m., and the other, *c*, considerably smaller, 4 in. The dotted line is a rough approximation of the power required to drive a 3400-lb. touring car, at road speeds in the relation of 22 m.p.h. to 1000 r.p.m. of the engine. It will be noticed that the difference between the carbureters *b* and *c* is insignificant at 2000 and disappears entirely at 1800 r.p.m. This is the reason carbureters of widely differing air-capacity may show so little difference in steady pulling torque at ordinary driving speeds.

Nearly every engineer remembers that sometime in his experience he expected to get a tremendous gain in power from a car by using a larger carbureter, and how very slight a gain, if any, was shown. Occasional instances have been reported in which the larger carbureters, and vacuum of less than 1 in. of mercury, gave better torque than carbureters more nearly the customary size, but I think that in each case careful investigation would have shown that the gain was due to something else than an increased delivery of the air charge.

Effect of Manifold Vacuum Upon Vaporization

As we have seen, decreasing the manifold vacuum tends in general to increase the torque, but another opposite effect is possible, due to changes in the rate of evaporation. Uniform mixture quality requires that the fuel-vapor density maintain a fixed proportion with the air-charge density. Also, we know that with the fuels used today the vapor density obtainable at ordinary atmospheric temperatures and pressures is much less than necessary to furnish a combustible mixture with air. Giving concrete estimates, at 80 deg. fahr. the vapor density of our average gasoline might average only about 1/45 of that of air, in which case, if you feed from the carbureter a fuel-to-air mixture of 1 to 15, only one-third of the fuel could and would vaporize. If, without change of mixture temperature, we close the throttle and

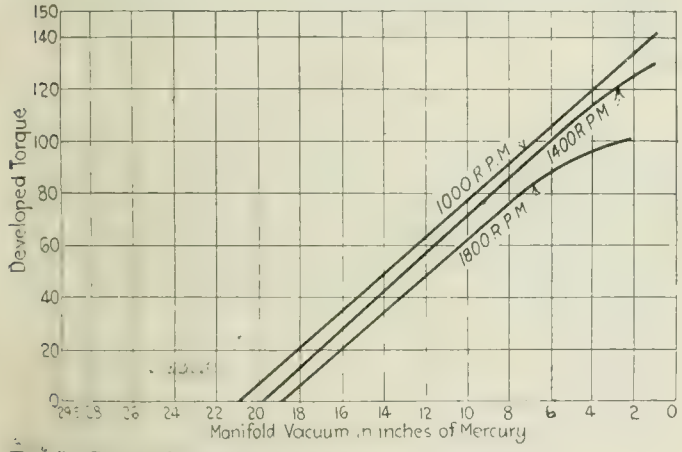

Fig. 2—Curves Showing the Relation between the Vacuum and the Torque Developed by an Engine

cut down the density of the air in the manifold to one-third that of the outside atmosphere, a fuel-air ratio from the carbureter of 15 to 1 in this reduced charge will give a vapor density of 1/45 that of atmosphere and under such a condition the manifold will be substantially dry. This results from the fact that for average temperatures and grades of fuel there is a torque limit below which the mixture will be substantially dry. Further throttle-opening may not increase the torque in proportion to the increased air-charge because of incomplete vaporization, a condition that can be remedied somewhat by enriching the mixture so as to get a greater vapor-density from the light elements of the fuel. Stated in another way, for every change of temperature, below a certain critical point, there may be a change in the mixture proportion needed for maximum power.

Another effect of this manifold vacuum condition, less evident in a theoretical consideration of the subject than in actual experimental work, is the invitation to air leakage into the intake system. This tendency to leakage is the highest when the weight of air-charge per cylinder is least, so that a very small leak at the exhaust-valves,

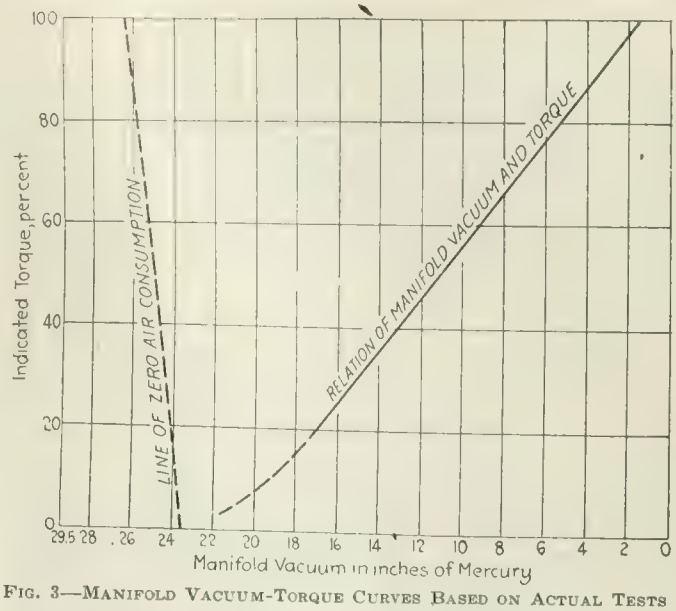
Indicated Torque, per cent
LINE OF ZERO AIR CONSUMPTION
RELATION OF MANIFOLD VACUUM AND TORQUE
Manifold Vacuum in inches of Mercury

Fig. 3—Manifold Vacuum-Torque Curves Based on Actual Tests

valve-guides or manifold joints may seriously disturb the operation of the engine under light loads, but show no effect on full-load pulling.

This relation of vacuum and torque explains the failure of the multitude of "economizing" devices put on the market in recent years, which consisted of suction valves designed to be mounted on the intake manifold, opening inwardly under the vacuum. Their opening was greatest when the throttle-opening and the air delivery of the carbureter were least, and in no possible way could they be made to exert anything like a uniform corrective effect upon the mixture at different engine speeds.

Air-Flow

A study of the air-flow in carbureters presents continuous difficulty because this flow, while in reality following known physical laws, is often deceptively disturbed by factors whose presence is not evident. As it is difficult for many to understand how air-flow in the carbureter can generate "suction," it may be best to begin our consideration of this subject with an analysis of the conditions of energy existing in the airstream.

According to our present conception of matter, a gas under pressure is made up of molecular particles in rapid motion, individually irregular as to direction and velocity, their average impact against the retaining walls developing what we observe as the gas pressure. The

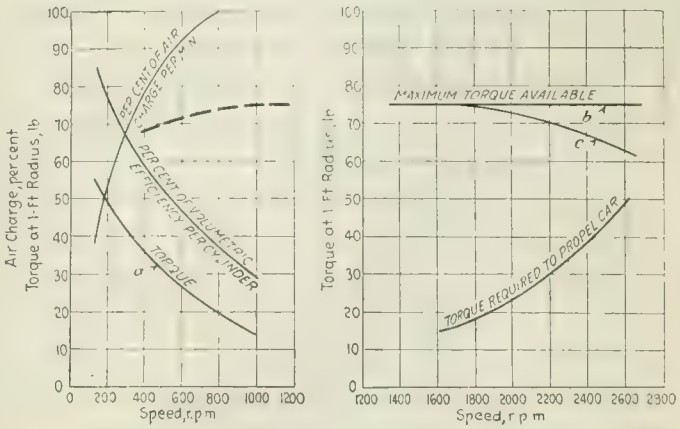
Air Charge, per cent
Torque at 1-Ft Radius, lb
PER CENT OF AIR CHARGE PER CYL'N
PER CENT OF VOLUMETRIC EFFICIENCY PER CYLINDER
TORQUE
Speed, r p m
MAXIMUM TORQUE AVAILABLE
TORQUE REQUIRED TO PROPEL CAR
Speed, r p m

Fig. 4—Curves Showing the Relation between the Torque and the Speed of an Engine

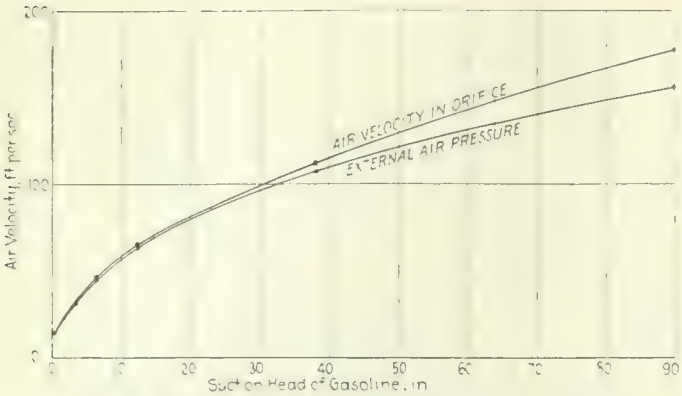

FIG. 5—CURVES OF THE AIR-FLOW AND AIR VELOCITY

amount of physical energy present in this body of gas will be proportionate to the number and mass of these molecular particles and to the square of their average velocity, the manifestations of this velocity also appearing in what we call the temperature. If the side of a vessel containing such a gas be opened into a passage of lower pressure, the gas particles will issue forth, but without any addition or subtraction of energy. The total amount of energy present in their motion must be the same as before, so that if this stream of particles has a definite direction, instead of being balanced in all directions as before, whatever velocity is gained in this one direction of flow, means a reduction in the relative molecular velocities normal and opposite thereto. That is, when a fluid enters upon a condition of flow, there is a corresponding reduction in its pressure. If we can get this conception of air at rest consisting of molecules in motion in all directions at a tremendous velocity, and of the air as it flows through the carbureter to the intake-manifold having this molecular velocity slightly increased in the direction of flow to the engine and correspondingly decreased in other directions, we will then be able to understand many of the apparent anomalies which our experimental determinations seem to disclose.

Much of our experimental uncertainty arises from the difficulty of measuring average pressures in the air-stream. In a carbureter or intake-manifold the stream is nearly always turbulent and non-uniform; also nearly any sort of pressure-measuring tube is likely to generate eddies around its measuring orifice, so that the greatest care is necessary for any reliable determination of the air-pressure distribution. If we consider the action of air-flow past a resistance concentrated at one point of the passage, such as the venturi tube in a carbureter, an equation based on the laws of conservation of energy takes the following form:

$$V = \sqrt{([2gP_1U_1]\ [N \div (N-1)]\ [1-(P_2/P_1)^{(N-1)/N}])}$$

where

V = the air velocity in the orifice in feet per second
g = the acceleration due to gravity
P_1 = the external air-pressure which is assumed to be 2102 lb. per sq. ft.
P_2 = the air-pressure in the orifice
N = 1.41
U_1 = the specific volume of the external air or 13.13 cu. ft. per lb.

The above, plotted in Fig. 5, is the form commonly incorporated in textbooks and gives the velocity at the throat in terms involving the pressure at the throat, which is variable. I have found that the application of this equation is more convenient if the velocity term is modified to give, instead of the actual velocity, the velocity that would exist if the density were the same at the restriction as in the air entering the carbureter. With such a velocity term it is possible to compute much more readily the weight of gas flowing under known areas and venturi throat pressures.

$$V_d = \sqrt{([2gP_1U_1]\ [N \div (N-1)]\ [(P_2/P_1)^{2/N} - (P_2/P_1)^{(N+1)/N}])}$$

The notation in this equation is the same as in the previous one except that

V_d = the velocity at the initial density or external air-pressure P_1 that would give the same weight of flow as the velocity V at the pressure P_2

These values also are plotted in Fig. 5. In both curves the rate of air-flow in feet per second is given in terms of the corresponding reduction of pressure in inches of head of gasoline of 0.75 specific gravity.

As is shown by an inspection of these equations, a peculiar condition arises when the air discharges into a vacuum or pressure of less than half the original absolute pressure. In general, the rate of flow increases with the drop of final pressure, but at a certain point, about 14½-in. vacuum, a limiting velocity is reached, which is, by the way, the velocity of sound. This has a bearing upon the flow of air past small throttle-openings. At all vacuums above 14½ in. of mercury the velocity of flow is constant and the quantity of air-flow going to the engine depends only upon the effective area of the throttle orifice.

THE VENTURI TUBE

From the viewpoint of the carbureter engineer we are interested in the air-flow only as a means of obtaining the desired fuel-flow; otherwise we would not interfere with it except at the throttle to control the power output of the engine. We obtain the fuel-flow by locating the fuel-discharge orifice in a region of suction or depression in pressure and naturally we will have the greatest range of action by getting the greatest possible depression for a given rate of flow. In other words, we desire equally an unrestricted air-flow, which usually implies low velocity, and a high suction. These two apparently opposing requirements have led to the general adoption in carbureter design of what is commonly known as the venturi-tube form of air passage, shown at the left of Fig. 6. The action of the molecular forces in passing through this shape of channel is obvious upon consideration. The rounding or converging entrance gives a free air supply right up to the point of greatest contraction. Upon passing this the components of pressure against the expanding taper

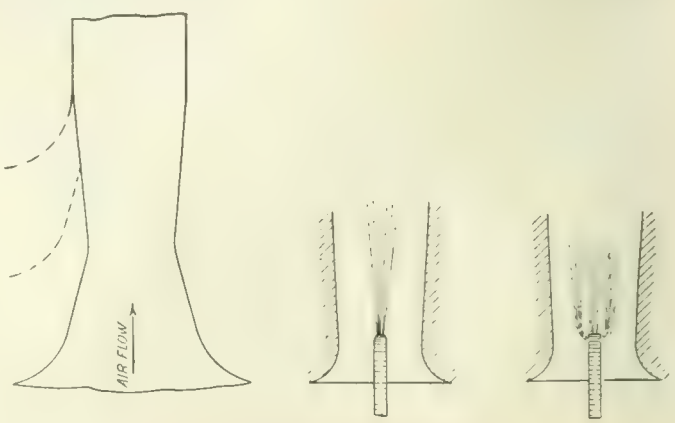

FIG. 6—TYPES OF CARBURETER JETS

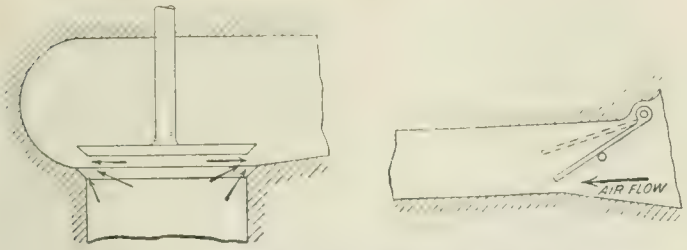

FIG. 7—WEIGHTED AND HINGED TYPES OF AIR-VALVE

of the walls yield an onward reaction that permits a rise of pressure. This rise or recovery of pressure at the outlet is what distinguishes the venturi-tube action from that of a bushing or choke.

One thing I do not understand, and for which I have never seen an explanation, is the fact that there is a definite limit upon the taper of the discharge part of the venturi tube; above 7 deg. on a side the action seems to decrease markedly, regardless of the velocity or, so far as we have measured, of the density of the medium. At smaller angles than this the efficiency falls off slightly, to an extent that might be due to the wall friction. The angle of entrance seemed to be of minor importance provided there is a smooth transition at the throat to the diverging contour. One point in venturi-tube design which is seldom emphasized is that the outer or collecting part of the entrance should be definitely larger in area

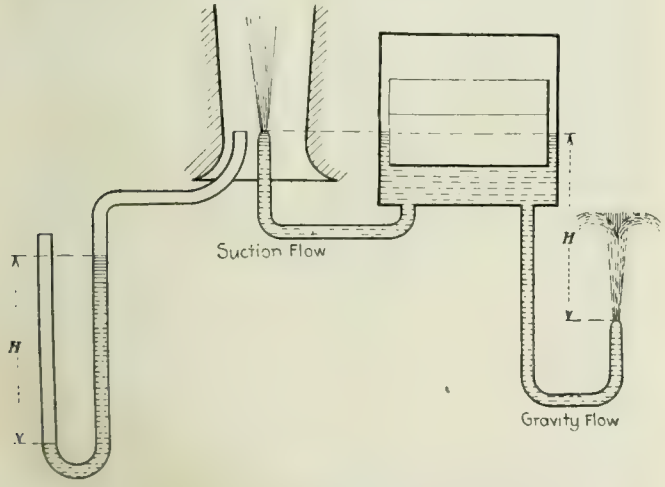

FIG. 8—SUCTION AND GRAVITY FORMS OF FUEL FLOW

than the outlet, in the same way that it is necessary to obtain a high coefficient of discharge for a given size of plain orifice. The dotted line at the left of Fig. 6 may show more plainly what I mean.

Another thing not generally understood is that the flow of gasoline in a venturi tube greatly disturbs its action, the derangement increasing with the rate at which gasoline is fed and the extent to which it is atomized. Some of the loss in energy of air-flow is occasioned in accelerating the gasoline from the jet, as shown in the views in the center and at the right of Fig. 6. In the former, which is the jet with the side outlets, the fuel is shown by its parabolic line of travel, which we have often observed, to accelerate to the speed of the air in a very short distance of travel; this generates a fine atomization, but considerable resistance to air flow. A jet such as that at the right does not exercise so great a restriction on the air-flow, but the fuel is not so finely broken up nor will the spray spread as widely in the same shape of passage as with the one shown in the center.

FLOW OF AIR THROUGH AIR-VALVES

The general conditions vary so widely with the design of carbureter that no general analysis of the flow of air through air-valves is possible. It should be mentioned, however, that very few carbureter air-valves give a constant pressure-regulation for the reason that there is a diminution of pressure on the surface of the valve near the approach to the opening orifice where the velocity is high. The area of this reduced-pressure section increases with the valve-opening. For instance, in the case of the

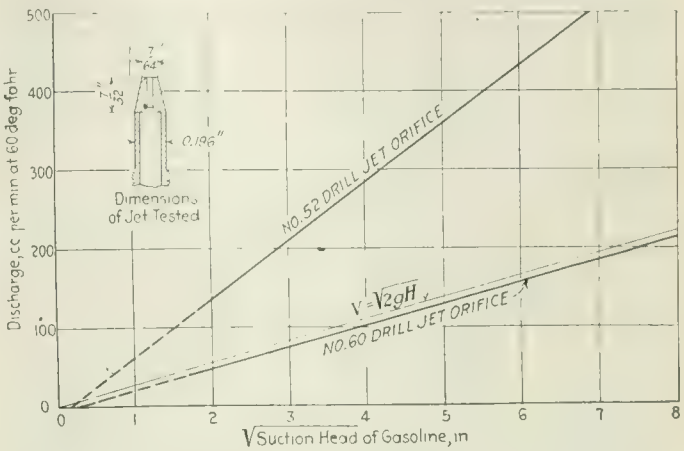

FIG. 9—CURVES OF FUEL FLOW THROUGH TWO CARBURETER JETS PLOTTED AGAINST THE SUCTION HEAD

weighted air-valve at the left of Fig. 7, if the area of the valve were 4 in. and the weight 2 lb., the valve would begin to open at a suction of ½ lb. per sq. in. and maintain this pressure above it for the first small opening. By the time the crack of opening became appreciable there would be a diminution of pressure around the circumference of the valve near the crack, so that the vacuum above it might perhaps reach ⅝ lb. As the opening increased, this action would increase still further. Therefore a valve of this type cannot be depended upon to give anything like a constant vacuum in the carbureter.

This action is still more marked in a hinged type of valve inclined slantwise across the air-opening. I have experimented with a valve such as that shown in Fig. 7 at the right and found that, with no spring at all, if I held it wide-open, it would suck to the position shown by the dotted line at a high engine speed. It will be noticed that the valve constitutes in effect a nozzle-shaped entrance and the fall of pressure within it is very similar

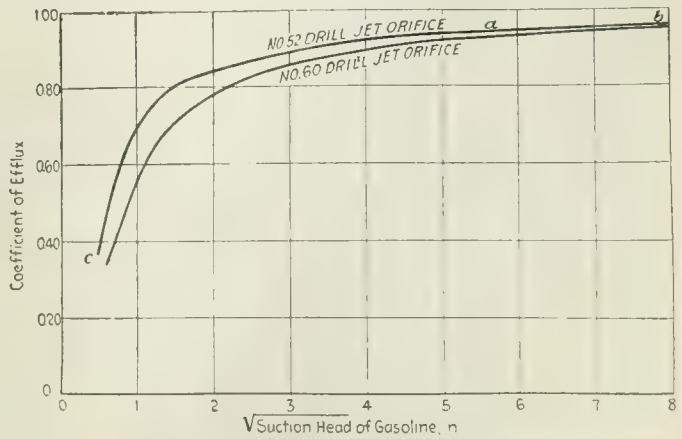

FIG. 10—THE ACTUAL MIXTURE PROPORTIONS OF THE TWO JETS WHOSE FUEL FLOW IS GIVEN IN FIG. 9

to that in the entrance to the venturi tube shown at the left of Fig. 6.

Fuel-Flow

The rate of liquid flow through an orifice of fixed size is customarily and most conveniently gaged according to the pressure causing the flow. This pressure may be that of gravity as shown in Fig. 8, or a difference of pressure measured in terms of the gravity head. In either case, under an equality of forces, the rate of flow should be the same. In our work we usually refer to the pressure difference causing the flow in terms of gasoline head. Disregarding the fluid friction in the passage leading to the jet of the gravity feed, Fig. 8, the velocity of the liquid discharged from the orifice should equal the velocity of a falling body which has passed through the distance h. Consequently, the rate of flow V should equal $\sqrt{2gh}$.

Fig. 9 shows approximately the flow, under gravity head, of a No. 52, 0.0635-in. diameter jet and a No. 60, 0.0400-in. diameter jet, plotted against the square root of the head. On such a diagram, a flow corresponding to the equation just mentioned would intersect the corner, as shown. If we assume that the line corresponding to this flow is an asymptote of the straight line curve of the No. 60 jet, and would give a uniform mixture proportion through a considerable range of air-flow, the actual mixture proportion of the jets would plot as shown in Fig. 10.

The relation of the actual flow to the mathematical one, which we may call the coefficient of efflux, is in my opinion due mainly to surface tension, for the following reasons:

(1) At times when this coefficient is low the fuel can be seen very definitely clinging to the tip of the jet
(2) Submerging the jet and providing means for drawing off the fuel as fast as it is supplied to a normal level, without imposing any additional suction on the jet, will give very close to a uniform ratio of flow to the square root of the head
(3) Introduction of air near the outlet of a submerged jet, with sufficient definite bubbling within and a splashing discharge from the jet will give a quantity to give a substantially straight-line mixture curve

It has been suggested that the height of the jet above the level is responsible for this deficiency. This height is to a certain extent responsible, but inspection of curves similar to those of Fig. 9 shows that the jet would need to be about $\frac{3}{8}$ in. below the level to give an approximately straight line.

It will be noticed that the flow from a plain jet has varying characteristics. If the jet can be used under suctions where its range of action extends from a to b, it will give a substantially uniform mixture. If, on the other hand, as in the traditional type of air-valve carbureters, its action begins at c, from c to a its coefficient of discharge is constantly increasing and an air-valve or similar regulation will be necessary to keep the mixture from becoming unduly rich. Some years ago, when we were working with air-valve carbureters, we found by experience that it was scarcely ever wise to go below $1\frac{1}{2}$ to 2 in. of suction on the plain jet for idling, that is, the lowest part of the delivery range. Below this point the action was very uncertain, the discharge being particularly affected by the temperature, which seems natural when we consider how largely the coefficient of efflux under these heads is governed by the surface tension. From time to time efforts have been made to get a large high-to-low speed range performance from a plain jet by coming down to very low metering heads at the lower end. As nearly as we can find out, this invariably results in the difficulties just mentioned, very uncertain action and undue sensitiveness to temperature change, as well as pronounced differences of action with fuels having different viscosity values.

It may be worthwhile at this time to analyze the matter of carbureter range. It seems to be the general belief that the range of a carbureter is governed by its range of air-opening sizes. This, is, of course, one limitation, but the size and capacity of the fuel orifice is equally responsible. As a sample computation, the No. 60 plain jet above described, at a minimum operating suction head of $1\frac{1}{2}$ in. will pass 23 cc. of gasoline per min. If we assume that the limiting manifold depression at high speed is 2 in. of mercury and that the efficiency of the venturi system employed in the carbureter is such that a 2-in. manifold depression gives 4 in. of mercury depression on the jet or 64 in. of gasoline head, the flow from the jet at this time would be 214 cc. per min., a ratio from high to low speed of 9.3 to 1. A greater range than this from such a jet can be obtained only by increasing the efficiency of the venturi by increasing the manifold vacuum, or by going lower on the low end of the metering curve.

A jet structure whose coefficient of efflux is free from the retarding influence of surface tension and gravity will meter down to very much lower heads, with the result of a considerably greater range. For example, with a minimum metering head of 7/16 in., a value easily obtained, and a maximum suction of 64 in. at a constant coefficient of efflux, the range will be equal to the square root of this suction ratio, or 12.1 to 1. In modern carbureter practice the venturi efficiency gives considerably higher suction than this, so that with the help of an auxiliary idling jet a ratio of 50 to 1 from minimum idling to maximum wide-open throttle capacity is easily obtained with fixed size air and fuel openings. It is obvious that a further marked increase of range would necessarily involve a proportional increase of both air openings and fuel jets, with considerable mechanical complication of the carbureter structure and a loss of the inevitable precision of metering characteristic of the fixed-opening type. In dealing with the question of carbureter range, it should be borne in mind that the maximum air demand of the engine will be reached at about the point of maximum high-speed indicated horsepower; also that the air capacity of a carbureter system is not a definite amount but increases considerably with a slight increase in the manifold vacuum.

There are a few miscellaneous points, which may be of interest, concerning the behavior of the fuel in the air column in the carbureter. The most noticeable characteristic of the gasoline, under observation of glass models, is the extent to which its action is governed by the surface tension. It clings to every surface it touches and would always much rather run along the surface than fly off. Very many jets that have been proposed as having fine spraying and atomizing qualities prove exactly the opposite, on account of this clinging effect. The fuel spray tends always to seek out and deposit at the points of low velocity. One of the most difficult things in developing a carbureter of very high speed-range is the problem of keeping the spray in suspension. To vary the fuel and the air openings in proportion is much less difficult than to ensure the gasoline rising steadily from the small low-speed air opening up to the throttle and the intake-manifold through the large body space necessary

for the full air opening. The tendency of the fuel to gather and load in this space is always very pronounced. In fact, much of the difficulty ascribed to lack of compensation in the jet delivery is really a failure to get the fuel from the jet to the throttle.

Mixture-Proportion Reqirements

Since practically all of our automotive applications of power have a reserve capacity, that is, their full power range is in excess of their normal operating power, it follows that the mixture-proportion requirements can to some extent be gaged as dependent upon the position of the throttle. At partially closed throttle maximum power is not a consideration, and a mixture of maximum economy is desirable. At wide-open throttle, however, the maximum-power mixture is desired in nearly every case, provided this can be obtained without too much sacrifice in fuel consumption. The records of the Society contain many experiments to determine the exact mixture proportion required to give these two characteristics, maximum power and economical fuel consumption and, as might be expected, the values obtained vary with every engine tested. It is obvious, first, that the fuel supply must be increased whenever there is any unequal distribution of the fuel, as the weakest cylinder must be supplied. Low fuel consumption, therefore, requires either a partial vaporization or fogging of the mixture, or else a high air velocity in the manifold along with the proper contour. Since the vaporization is so much more complete at closed than at open throttle, our distribution troubles and the manifold contour are important almost only at wide-open throttle and for this reason, with the average motor-car engine, we can run on a thinner mixture at part throttle, or above about 12-in. manifold vacuum, than at wide-open throttle. That is, the mixture of maximum power at part throttle is nearly always leaner than the mixture of maximum power at full throttle. Under circumstances where the fuel evaporates completely in the intake-manifold, the leanness of mixture that can be used is limited by the ability to ignite and propagate combustion, for which conditions are more favorable at the full compression of a wide-open throttle than at the lower compression of part throttle, with also a higher percentage of exhaust dilution.

We do not find any reliable evidence that an increase in the fineness of atomization beyond a certain point, reached in nearly all carbureters, will give any effect upon power or fuel consumption, provided the discharge from the jet is steady and not intermittent. It seems that vaporization reaches its limit at 100 per cent atomization. It is, of course, worthwhile to keep the spray off the manifold walls so far as possible.

In illustration of the foregoing, Fig. 11, is a typical mixture-proportion curve. The wide-open throttle setting, being that of maximum power, will usually be uniform for intermediate and high speeds but somewhat richer at low speeds, both because of poorer manifold conditions at this time and because detonation is less likely to occur with such a mixture. The closed-throttle range may be leaner than that at wide-open throttle at ordinary driving speeds and such a setting will give exceedingly smooth operation when the engine is in good condition. When the valves begin to leak, a richer mixture may be needed to cover up partly the irregularity of firing charge. At idling the very thin air-charge, the high percentage of exhaust residue and the uncertain leakage of air through the valve-guides make a very rich mixture necessary. The exact mixture-proportion re-

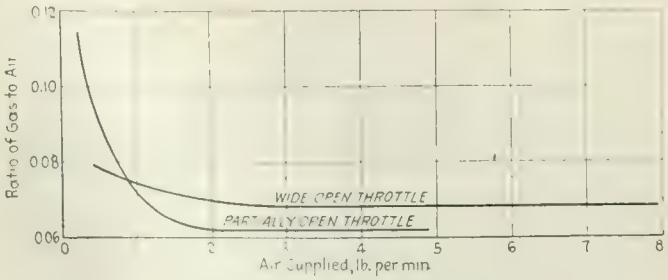

Fig. 11—A Typical Mixture-Proportion Curve

quired under each of these conditions will depend, as can readily be understood, upon the individual characteristics of the engine and the fuel used. Also, they vary quite definitely with the service for which the engine is used. An effort will be made to analyze these requirements under the different divisions of passenger cars, motor trucks, tractors, motorboats, airplanes, racing cars and dynamometer tests.

Passenger-Car Mixture Requirements

For passenger-car service the predominant requirement to-day is ability to accelerate from closed to open throttle at the moderate or legal range of speeds. Practically all carbureter adjustments are made to give this acceleration, most drivers gage the ability of their car by its response to the throttle, and a large part of our factory demonstration work on the road is directed toward the attainment of this important point. This is natural and proper because the full power of the engine in present-day driving is nearly always used to give a gain in speed, except in a few hilly localities, and many times when it is called upon, the safety of the driver depends upon its response. At present, country roads and city streets alike are so generally crowded that the time made on either a long or short trip depends more upon the ability of the car to thread its way through traffic, to slow down and pick up quickly, than upon the maximum speed. This matter of acceleration is so important that nearly any carbureter will receive favor, regardless of faults in other details, provided it fulfills the function of giving prompt and positive acceleration.

So far as the action in the carbureter is concerned, acceleration requires, first, a mixture-proportion and condition of vaporization that will pull full power at wide-open throttle and low speeds. I might comment on the fact that while it is customary nowadays to take power curves from 3500 to 800 r.p.m., it is very seldom that the dynamometer horsepower curves are carried down much lower. But just as soon as we make a carbureter test on the road we try to get acceleration from something like 1 m.p.h., which means full power from 60 r.p.m. up.

We further find that in addition to a powerful steady running condition, acceleration is greatly improved by a temporary excess of gasoline. The need of this excess feed was very clearly explained by the recent experiments of the Bureau of Standards with glass intake-manifolds. It was found that at wide-open throttle, with ordinary fuels and the ordinary range of temperature available, a large part of the gasoline travels from the carbureter to the cylinder along the manifold walls at a rate of speed relatively much lower than the air speed. At closed throttle so much greater a percentage of the fuel evaporated that almost none was on the walls. Now, in throwing the throttle open from the closed position, the wall-flow took a considerable time to become established, dur-

ing which period the cylinders were receiving only the percentage of gasoline that evaporated. Under this condition, with a normally lean mixture from the carbureter, the mixture reaching the cylinders was very much too lean for power. By raising the proportion of the gasoline fed to the air, the amount of evaporable elements could be increased to a point where they alone would supply a firing mixture without the aid of the heavier elements. It is obvious that continuous use of such a mixture would mean a considerable waste of fuel, but the actual amount needed to fill the temporary deficiency on acceleration is small. We find from experiments that a thin steady running mixture, with means for temporarily enriching the mixture as necessary for acceleration, will give better acceleration than a carbureter without such an accelerating device, set so rich that the engine lopes in driving along the street at closed throttle. It is rather remarkable that the application of different means of heating the walls of the manifold does not do away with the need of this accelerating extra fuel supply, although it cuts down the amount required. In comparison, the use of hot air on the carbureter comes nearer giving acceleration on a normal mixture. Visible observation shows that when such conditions are attained the fuel evaporates almost entirely within a few inches from the jet and that there is much less wall-flow. According to the analysis just given, the extra charge on acceleration should be delivered at the moment of the change from high to low manifold-vacuum, and we find in practice that this is the case. This requirement cannot be fulfilled with precision by accelerating means dependent upon the throttle opening nor upon an increase of the carbureter suction, since neither of these coordinates invariably with the fall of the manifold-vacuum; on the other hand, some precautions are necessary to prevent the large accelerating charge that is necessary for some engines from all going into one or two cylinder ports. However, too much is far less objectionable than too little and there are a number of satisfactory accelerating devices in use which do not conform entirely to the above statement of requirements.

Fuel Economy.—We all try to obtain low fuel-consumption as a characteristic of passenger-car operation. Since the average speed of a car in most sections of the country lies between 10 and 35 m.p.h. and at closed throttle, the normal driving range indicated in Fig. 1 should be set for best economy, although in practice drivers will not use such a mixture setting unless it is possible at the same time to get good acceleration.

There are two factors, really wholly outside the scope of this paper, that have much to do with the fuel consumption. The first is the mechanical efficiency of the engine. With the average 3500-lb. car having a 4½ to 1 gear-ratio about 5 hp. is required to drive the car at a speed of 20 m.p.h., about 1¾ hp. to overcome the loss of pumping against the manifold-vacuum on the intake stroke and about 3½ hp. to overcome the friction of the engine, a mechanical efficiency of 48 per cent. As many cars are delivered with their engines very stiff, for the first 2000 miles the mechanical efficiency is less than 35 per cent. With, for instance, a 2¼ to 1 gear-ratio in a four-speed gearbox, the pumping loss would be about 1 hp. and the engine friction about 1¾ hp., so that at the same power output the mechanical efficiency would be about 65 per cent. If the 4½ to 1 gear-ratio gave 16 miles per gal., the 2¼ to 1 ratio should give 22. A trial of a well designed four-speed gearbox with a flowmeter indicating the fuel consumption, will show what a tremendous effect this factor exerts. An average value of the torque required to propel a car at moderate speeds on smooth level roads is 50 lb. per ton of car weight. At a fuel consumption of 0.65 lb. per hp-hr. a 3500-lb. car would travel 41 miles per gal. and a 2000-lb. small car, 72 miles. The difference between these figures and what we actually do make is due less to deficiencies in our engine cycle than to the fact that we operate at so low a percentage of the normal engine torque. A fuel-injection engine would probably be even less efficient under these same conditions, on account of the extra power required for driving the various auxiliaries not found on our present type of engine.

Another factor that we find in our service stations raises the passenger-car fuel consumption is the tendency of the average driver to retard the spark to prevent the engine from knocking at wide-open throttle, and leave it that way for steady driving at closed throttle. That is very common with cars having high-compression engines and poor manifold systems which invite the accumulation of carbon in the combustion-chambers. For ordinary legal-speed driving at from 14 to 16-in. manifold-vacuum, the spark should be advanced almost to the point necessary for maximum car speed.

Hill-climbing at ordinary speeds is largely a question of proper mixture proportion and favorable conditions of vaporization. The capacity of the carbureter does not enter much into this because nearly all carbureters, as has been brought out, are adequate in size for the speeds at which hills are climbed. At low manifold velocities and wide-open throttle with the present heavy fuels there is an accumulation in the manifold that increases rapidly and if it goes into the cylinders in occasional slugs will give the action known as "loading." It is not generally appreciated, but a hill test can be made a very delicate demonstration of the nature of the torque curve of a car, particularly with engines whose torque drops off at low speeds. Referring to the dotted-line curve at the left of Fig. 4, if the inclination of the hill is such that it just equals the torque of the engine at this speed, any slight increase that could be made in the torque would increase the engine speed to a region of increased torque whereby the engine would accelerate and continue to gain speed, provided the inclination of the hill were constant. On the other hand, the merest diminution in torque, even a single miss-fire in one cylinder, would cause the engine speed to drop slightly to a region of decreased torque, under which the car would start to lose speed still further and it would probably be necessary to shift gears within 60 ft. In the hill testing that I have witnessed, particularly before proper methods of manifold heating came into vogue, this point was a source of very great waste of time and much useless work. The skill of the driver and the natural variations of manifold temperature made big differences in the hill performance and all engaged in the test used to rack their imagination to find explanations for the different results we seemed to find.

Speed, in the average driver's estimation, is what we might characterize more definitely as good acceleration up to 45 m.p.h. Such determinations as we have been able to make show that the power required for high speeds crosses the curve of engine torque at such an angle that considerable variations of torque at the very high end make only small changes in car speed and such apparently small factors as wind direction and wheel-traction road-surface make very considerable differences. For long stretches and speedway work speed is simply a question of having enough air and the right amount of

fuel to go with any type of carbureter which I know of that is positive in its operation. Our service experience indicates maximum car speed is to the average car owner the least important of all requirements; not even 1 per cent of our complaints are directed to this point. It is not so much that the drivers do not think they want speed as that they do not use it often enough to know whether they have it, and it takes a very considerable loss in engine power to make a change in maximum speed that the average driver can detect.

A carbureter for any service should, in my opinion, be reasonably simple and positive in operation. It should be possible for production carbureters to be made alike and so that after any reasonable overhauling any one can be restored easily to its original condition. The carbureter should be as wearproof and dustproof as possible, so that it will not deteriorate or change adjustment during the life of the car. This is rather difficult to insure with carbureters of the variable gasoline orifice or metering-needle type. In every case this type of carbureter should have a dashpot piston to keep the attendant air-valve from hammering and wearing the seat of the metering-needle seat. It is advantageous to have the idling mixture adjustable separately from the remainder of the mixture range, because slight manifold leakages, valve-stem leakages and the like affect this proportionately much more than other parts of the mixture range. The action of the carbureter should be unaffected by the jolting of rough roads.

Motor Trucks

The range of operation of motor trucks is such that the engine works through a lesser range of speeds than in the case of passenger cars, and the manifolds are usually designed so that this speed range corresponds with the higher range of manifold-velocities, with the result that carbureting conditions are much easier. Also, four-cylinder engines are as a rule easier to handle than those of larger numbers of cylinders, due mainly to conditions of manifold distribution. These advantages are offset, however, by the practice, which is extensive in motor-truck construction, of dropping the carbureter very low down to get gravity fuel-feed from a gasoline tank under the seat. This necessitates a long manifold, and very few trucks indeed are equipped for proper heating of the fuel charge after it leaves the carbureter, with the result that the fuel condenses in the manifold and the difficulties of acceleration are considerable. The governor valve and its chamber also act as intercepting and loading points for the fuel spray. I believe that experience will show that the life of the engine in a motor truck can be very greatly prolonged by proper design of the intake-manifold and correct selection of the carbureter and that this consideration, even more than that of fuel consumption, will soon lead to the use of more effective provisions for vaporization on motor-truck engines.

Tractors

The duty of a carbureter in tractor work is considered easy because the load is supposedly steady. Actually, however, there are periods in service when flexibility is needed badly. With kerosene as fuel it is possible with high manifold-velocities and by use of a carbureter having good atomizing properties and a charge well diffused through the airstream, to perform pretty well with a low mixture-temperature, provided the cylinder jackets are fairly warm. Even so, we can scarcely say that successful general operation on kerosene has been attained as yet. The tractor carbureter should be of the simplest construction and entirely dustproof.

Motorboats

As will be noted from the diagram at the right of Fig. 1, the range of performance of an engine attached to a propeller falls within very definite limits, also the condition of unfavorable evaporation at wide-open throttle is encountered only under the correspondingly favorable condition of high manifold-velocities. The requirements of motorboat carburetion are, therefore, the simplest of any automotive branch. Due to this condition, however, only recently has there been any pressure upon the designers to provide for adequate heating of the intake-manifold, and very many engines are in use today whose performance suffers on this account. Nearly all the later designs show that these considerations are now being given attention.

Airplane Carburetion

In airplane service the propeller load and the fact that relatively highly volatile fuels are used make the engine typical of this field the easiest on which to demonstrate carbureter performance on the dynamometer test stand. But in the air there are a number of special requirements which render the airplane field perhaps the most difficult of all the branches of carbureter work. First, the mixture tends to grow richer with increase of altitude, in the proportion of the square root of the change in the air density. Second, it is desirable that the carbureter should function properly in every position that the airplane may assume. Third, the carbureters are usually more or less subject to the deranging influence of the propeller blast, which sometimes almost equals in magnitude the velocity of the air past the metering jets of the carbureter. It is nearly always possible to compensate for this by balancing the float-chamber of the carbureter on the air entrance. Fourth, the high mechanical efficiency of airplane engines and the fact that a number of carbureter units are usually employed on one engine, make it very difficult to obtain a satisfactory idle and low-speed range, and, on this account, positive and certain acceleration. When we add to these points the requirements that the carbureter should give at all times the smoothest possible firing of the engine, that effective precautions must be taken against any stoppage of the jets or mechanical failure and that every effort should be exerted to prevent backfires, it is evident that much work is necessary before a perfect airplane carbureter can be produced.

Carbureter and Engine Tests

In our demonstration work throughout the country we encounter widely different methods of engine testing to determine carbureter merit, some good and some, in my estimation, not so good. In view of the importance of this work it seems worthwhile to set forth, for discussion at least, what seem to be the essentials for obtaining accurate and trustworthy information.

Dynamometer tests should obviously reproduce conditions of actual operation, not only as to the temperature of cooling water, the air around the engine, and the air entering the carbureter, but also as to speeds and loads. The full power-range of a passenger-car engine should be brought down to the speed demanded in road operation, while the fuel consumption should be taken at loads corresponding to normal driving. Most important of all, in my estimation, the power should be plotted as torque against speed. The method in general use at present of

plotting the horsepower, which is the torque times the speed, against the speed, results in a form of curve in which undue prominence is given to a relatively unimportant and rarely used part of engine operation. When one looks at such a power curve the eye instinctively goes to the peak and gives this consideration to the exclusion of everything else. Yet nearly every car makes its maximum road speed at a higher number of engine revolutions than that of the peak of the power curve, so that it is the power beyond the peak that determines the maximum car speed. Also the horsepower-speed curve is very unsatisfactory as a means of indicating low-speed pulling ability, or as a basis for fuel-consumption tests at part load. In fact, it does not at all depict the power performance or ability of a car, except possibly for advertising purposes.

Since the power of the engine at full air-charge is dependent upon the density of the air entering the carbureter, this should be recorded, and corrections made for temperature and barometer in all tests of maximum torque. Care should be taken to have the air supply clean and not contaminated by the exhaust. If the intake-manifold is near the exhaust-manifold, at high speed and full load the radiation from the latter may heat the intake unduly and cause the power to fall off.

For fuel-consumption tests the friction horsepower of the engine should always be recorded and comparisons made upon the basis of indicated horsepower. This is particularly important with part-load tests.

Since present-day requirements are such that the carbureter adjustment used in service is determined by the ability to accelerate, it would be of great value to have a dynamometer equipped with a flywheel disc to give an inertia equivalent to that of the finished car. A disc of this sort is in use at the Bureau of Standards.[2]

There should by all means be in plain view a thermometer giving the intake-manifold temperature, without which intelligent comparisons cannot be made. It is advisable also to have a gage reading the intake-manifold vacuum, as this, along with the temperature, governs the rate of vaporization and the extent to which the mixture delivered by the carbureter will approximate that received by the cylinders. A flowmeter is very useful to give a general indication of the fuel consumption under different conditions of driving.

An easily read accelerometer is of great value. It not only gives an idea of the power developed but can also be used to read the road and wind resistance, from the rate of deceleration with the clutch out, thus removing two otherwise unknown variables in a fuel-consumption test.

It is believed that the foregoing covers the main points to be considered in the development of proper carbureter action. It will be noticed that this work falls definitely into two distinct parts; the first, a joint responsibility of the engine designer and the carbureter engineer, being to determine the specific mixture and vaporization requirements of an engine; and the second, for which the carbureter engineer alone is responsible, to produce an instrument that will deliver reliably and consistently such a fuel-charge with as favorable vaporization conditions as can be obtained. Successful results can be obtained only by close and cordial cooperation. I am glad to say that in the past few years this cooperation has been general and that our work has been more efficient and much more pleasant on this account.

[2] See THE JOURNAL, August, 1920, p. 131.

THE INTERNAL-COMBUSTION TURBINE

THE largest internal-combustion turbine yet constructed appears to be that due to Mr. Holzwarth, who published in 1911 some very meagre details of a turbine, designed by him to develop 1000 hp., and which, at the outset at any rate, only yielded 150 hp. It was later on claimed that by modifications and improvements this figure had been raised to 450 hp., but the report was not one to inspire confidence. Reports are now to hand as to another Holzwarth turbine built by Messrs. Thyssen, which is claimed to have developed 984 hp., with an overall thermal efficiency of 26 per cent. It is claimed that the waste heat supplies all the energy required to operate the steam turbine compressor that compresses the charge to 33 lb. per sq. in. absolute before ignition. In view of Holzwarth's original paper and claims, this report must be received with some caution. The general method of operation embodies no novelty. The charge is compressed into an explosion-chamber and fired, expanding through a nozzle onto the buckets of a turbine wheel. As the pressure in the chamber falls the velocity of efflux diminishes, a condition that must involve somewhat serious losses in both the nozzle and the buckets. Moreover, the apparatus is necessarily complicated by the installation of a steam turbine compressing plant.

An overall efficiency of 26 per cent means an expenditure of nearly 10,000 B.t.u. per hp-hr. Such a figure is probably not beyond the reach of the steam turbine, and some interesting figures may be expected when certain extra high-pressure plants now in course of completion undergo their tests. The limit of steam turbine efficiency is certainly not yet attained, at least so far as the reaction type is concerned. As yet the steam-reaction turbine has not attained as high an efficiency as the corresponding water-operated turbine, but there is no obvious reason for this. In view of the foregoing there seems little likelihood that any form of internal-combustion turbine, of which particulars are yet available, will prove a commercial success. All obvious lines of development have in fact been fairly thoroughly explored, with disappointing results, a condition of things that tends to convey the impression that the difficulties are inherent in the system and not in its details.

In addition to the difficulty of devising a cycle that shall be at once efficient and mechanically simple, there are certain to be grave troubles from the rapid wasting of nozzles and buckets under the flow of white-hot gases. Hitherto experimenters have fallen back on carborundum for the nozzles, but this material is obviously unsuitable for the buckets. Could the massive tungsten used for the metallic-filament lamps be obtained in bulk at a sufficiently low cost, the bucket problem might be solved, since this metal has a strength comparable with tool steel, combined with a melting-point of nearly 3000 deg. cent. (5432 deg. fahr.)—*Engineering* (London).

PRECISION IN MANUFACTURE

IT was well proved in the war, and it is patent to any manufacturer operating upon a large production scale, that millions of dollars are lost through wastage because mechanical pieces vary a few millionths of an inch in measurement. The host of small-scale inspectors, filers, fitters and sorters who do not belong to the technical inspection or engineering staffs are paid wages because other workers make mistakes in work.—F. W. Hersey in *Michigan Manufacutrer.*

Automobile Locking-Device Classification and Theft Insurance

By A. R. Small[1]

Metropolitan and Cleveland Sections Paper[2]

ONE certain way of eliminating insurance losses caused by the theft of automobiles is for the companies to refuse to write this form of coverage, and many underwriters would feel much relieved if this solution were generally adopted. Others say that this identical solution will obtain automatically when and if the premiums charged are further increased. But it is the business of insurance to reimburse a property owner for loss and it is the proper ambition of the modern insurance company to offer 100 per cent service or protection. Accordingly, we must presume that insurance protection against the theft of automobiles will continue to be furnished and we can consider ways and means of restricting the losses to an extent which will permit the protection that insurance affords to be provided at a non-prohibitive cost.

In the early years of the automobile the theft problem did not exist. Automobile-theft insurance, when and if written, was included by the agent and his company for but a nominal increase over the premium charged for fire insurance, merely to make the coverage complete. Persons who could drive cars were few. The appearance of a new or strange car in a community was a matter of neighborly comment; its history was known or readily ascertained. Without a closer analysis of the development, volume production and general utility became features in the definition of the automobile-theft problem. Statistics show at least 9,000,000 automobiles of the private passenger-car type licensed for use in the continental United States. It is probably a conservative estimate that there are three persons to every car now in use or from 20,000,000 to 25,000,000 persons who are provided with the knowledge for automobile operation.

Insurance losses from the theft of automobiles first reached serious amounts perhaps in 1913 and certainly by 1915. Most of the losses of that period did not involve theft for illegal sale and money gain but were from damage to the car resulting from unauthorized joy-riding. The general impression among automobile underwriters is that this cause of loss is not now a predominating factor of the total loss. Shortly after this the losses from drive-away disappearances caused disturbance, but this source of loss has largely vanished because of the comparative readiness with which railroads now furnish box cars for shipment. Whenever organized theft of automobiles upon a commercial scale had its beginning, its successful growth had become plainly manifest in 1917. From 1918 to 1920 inclusive, in part because of the universal list-price increases, when the used-car value became enhanced nearly 100 per cent of its original value as a new job and when decreased production due to war conditions delayed deliveries of new cars, the theft loss-ratio was shockingly large.

The so-called moral hazard is a factor in every general risk for which insurance is written. Its share of the gross loss ratio is not capable of analysis further than to observe that it varies with the economic situation of the people as a whole and with the public sensibility of general right and wrong. Normalcy, toward which all are working, should place this element in the background. There are those who assert that the use of stolen automobiles in holdups, bank robberies, liquor running and smuggling is merely a phase of this moral hazard, reflecting the extent to which the present moral sense of the general public is abnormal, but it is sufficient to record that such uses have made a new market for the stolen car and added perhaps to the list of active thieves.

The automobile-theft problem from the insurance viewpoint includes in its defining lines the following: (*a*) the automobile has become a utility, (*b*) which is generally available and (*c*) readily operated by the general public (*d*) without general comment; (*e*) the automobile readily lends itself to illegitimate use by the irresponsible joy-rider, (*f*) to organized theft for profit in the sale of stolen cars and (*g*) to vicious purposes to which the use of stolen automobiles is secondary. If this be the problem, it appears that features (*a*) to (*d*) will continue to grow with the industry. A job which does not have a general-utility value will not be a "commercial" proposition from the thief's viewpoint. As production schedules increase, more cars become available to the thief. A design that is not operable readily by the general public will have a limited legitimate distribution and likewise a restricted stolen-car sale-value. Only special bodies or freak jobs attract attention now. Accordingly, preventive or protective measures against the insurance losses from the theft of automobiles must take the direction of retarding their availability for illegitimate uses, and not combat the items that reflect the growth and prosperity of the automobile industry.

Theft Retardants

It is pertinent to emphasize the use of the word "retard," in contrast with "prevent" or "protect." The property of mobility being a primary essential of the automobile, prevention of theft while mobility persists is not possible, generally speaking. This has been recognized by Underwriters' Laboratories by the classifying of automobile locking devices as "theft retardants." It is believed futile to proceed on the theory that prevention is practical. In studying the sources of automobile thefts a clear distinction becomes evident immediately as to the efficiency necessarily demanded of retardants protecting against (*e*) and (*f*) or (*g*). That such a distinction exists between (*f*) and (*g*) is not so clear; in fact, it may not exist within the bounds of practical procedure.

The first locking device was the simple ignition-switch or plug having for its primary purpose a means for stopping the engine. This did not long suffice to prevent unauthorized use. Ignition-switches equipped with tumbler locks were the next development. Subsequently a

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[2] The portion of the paper relating to locking-device classification was presented in New York City and that on other forms of automobile insurance, in Cleveland; the two were afterward combined for publication, although that was not the original intention of the author.]

more general knowledge of the wiring systems used on various makes of car has decreased materially the protection afforded by this type. Since 1915 various other locking means or methods have been developed. More than 100 makes, patterns or styles available as accessories are now classified by Underwriters' Laboratories, and some 15 to 20 are being furnished regularly as stock equipment by automobile builders. The several methods of locking comprised in this group are

(1) Ignition circuit locked open
(2) Gasoline feed line locked closed
(3) Intake-manifold locked closed
(4) Exhaust line locked closed
(5) Shifting gear locked in neutral
(6) Shifting gear otherwise locked
(7) Clutch pedal locked in depressed position
(8) Steering-wheel locked in the free position
(9) Steering-wheel locked in a fixed position
(10) Chains, clamps, bolts or other fixtures securing a wheel to the car frame, a lamp-post or a telephone pole

In at least 90 per cent of these devices a cylinder lock with a key of the pattern commonly known as the Yale is used. On one well-known high-priced stock car locks were provided on the ignition-switch, spare-tire holder, toolbox, hood clamps and at other points. These several locks on each car were operated by a common key and there were but 10 key-changes in the series; so access was necessary to only 10 cars to secure wax impressions for making a set of keys with which any car of this make could be stolen. The Detroit police once exhibited two complete sets of 50 keys each that had been taken from a thief. These covered the entire output of two popular makes of car. In view of such conditions the present requirement of Underwriters' Laboratories for at least 200 key-changes will not seem severe. Hardware stores and locksmiths sell blanks for various patterns of so-called Yale keys; hence our regulations call for keys with milled slots, duplicates for which cannot be secured in this ready manner. To prevent picking, tumbler locks must have not less than three pins and, to avoid forcing, key-slots should be flush in the cylinder face. Locking cylinders must be mounted properly to prevent ready removal and set-screws must have riveted heads if used for this purpose. In a similar way the operations and mechanical details must be studied and limitations set up to avoid the easiest ways of installation and of removal, but the theft of cars cannot be prevented. An extreme method reported as having been employed several times by a gang of organized thieves is that wanted cars were spotted and the habits of the drivers learned. When a car was left alone, a furniture van would be drawn up, a ramp would be lowered and the car hauled by a winch into the van. With the car inside the closed van would disappear. There is a practical limit to what can be demanded of locking devices. Given time, tools and freedom from apprehension, any locking device practical for use can be defeated. Some damage to car fixtures may result, but never to the extent of eliminating the profit to a thief.

It is believed that where the idea of money gain is not present, the regular use of a locking device of a type listed by Underwriters' Laboratories is effective in preventing the theft of cars for joy-riding; and that the regular use of such locking device is more than 50 per cent effective in causing commercial stealing to be confined to cars not so equipped. The use of standard locking devices is likewise not less than 50 per cent effective in defeating thefts when attempts against cars so equipped are actually made. Considering the number of stolen cars which are not equipped with modern standard locks and others stolen while left unlocked by the owner, an actual "fielding average" of 80 per cent or better is claimed for the present listed types and patterns.

Volume of Automobile Theft Insurance

Detailed statistics as to underwriting experience or volume in automobile-theft insurance are not available. The following figures are deduced from data given in automobile editions of several insurance publications. Approximately 350 insurance companies write automobile-theft insurance. Because of the limitations placed upon insurance practices by State laws and restrictions, this insurance is never written except as a side line of automobile fire insurance. In 1920 these companies assumed a theft liability of several billion dollars for an estimated premium of about $60,000,000. The figures show what is called an underwriting loss for the business, from which a computation can be made showing a distribution of this $60,000,000 premium-income as given in Table 1.

TABLE 1—DISTRIBUTION OF PREMIUM INCOME

Items of Cost	Percentage of Revenue	Amount
Sales Expense	25	$15,000,000
Overhead and General Operating, including reserve requirements	20	12,000,000
Detection and Adjusting Cost	5	3,000,000
Taxes	4	2,400,000
Payments on Claims	55	33,000,000
	109	$65,400,000
Net Loss	9	5,400,000

It is purely coincidentally that by a similar course of reasoning I conclude that of the 9,000,000 automobiles registered for 1920 not more than 5,400,000 are covered by any form of insurance protection, showing an average underwriting loss of $1 per car. But when we consider that companies writing only public-liability insurance, without the theft coverage included, take at least 40 per cent of the total automobile premiums collected, the estimate shows not only an average underwriting loss on the theft business alone of about $2 per car but, in addition, cash actually paid out for claims of at least $10 per car insured against theft. This indicates an assumed number of cars insured against theft of approximately 3,000,000, with an average premium of $20 per year and an average face value of $1,000 per policy, or an average rate of 2 per cent after all deductions.

But what is the significance of these admittedly questionable figures in explaining the underwriting loss, which has been referred to as averaging $2 per car for theft alone? The rate allowance, not including the penalty, for a labeled locking-device policy-warranty of 15 per cent produces for an average car a reduction of $3.50 per year. This amount is sufficient to take care of the underwriting loss with a margin sufficient to show a profit in the business. Assuming five years as the insurance life of the average automobile, it will be seen that the companies buy these locks at an average price of $17.50 each. It is known that not more than 1,000,000 labeled locks are in use and that at least one-half of these are on 500,000 of the 6,000,000 automobiles which are not insured for theft. Accordingly, the views of the executives of the insurance companies as to the value of this form of theft retardant seem to harmonize with those of 500,000 automobile owners.

At various times attempts have been made by our en-

gineers to classify or grade automobile locks as to their relative efficiency. So far such classifications are of sentimental rather than practical significance. The insurance companies differentiate the "accessory" and the "built-in" types and offer a practical consideration of 5 per cent additional credit for the latter. This is not especially to recognize superior merit in the locking devices or methods, but to acknowledge the value of avoiding defective or faulty installation and of selecting a type suitable for the problem presented by the special features of the design of a particular make of automobile. Further, it is felt that standard locks on the entire output of an individual maker is of practical benefit in the situation.

Our engineering staff is preparing a new set of requirements for the performance of automobile locks. Presumably, when finally adopted, these will constitute a composite of the present standards. But it is certain that such protection against theft is adequate only for a day or two, if that long, for the reason that there is no standard thief. Accordingly, education must be resorted to for whatever fraction of the total risk remains when the estimated efficiency of locks, watchmen and all other retardants is considered.

Other Forms of Automobile Insurance

Having discussed the methods of classifying locking devices to retard the theft of automobiles, let us consider other ways and to what extent insurance applies to the automobile and to problems of its design. The insurance companies are required to report various statistics with regard to losses and other items of the business but, because it is comparatively new, the statistics with regard to automobile insurance are not required in the same detail as for fire insurance, and it is difficult to establish the real extent of automobile contact with the insurance business.

The five common forms of insurance for automobiles are those of fire, theft, collision, property-damage and public liability. We already have considered the theft problem at length. Public-liability and property-damage insurance have much in common and features of design bearing on them will be considered ahead of the items bearing on the fire and collision hazards.

About 430 different organizations sell automobile insurance of one form or another, and something like 70 of these sell only liability, property-damage and collision insurance. These 70 organizations collect about $70,000,000 in premiums; the remainder collect $113,000,000 for fire, theft and collision, so that the statistics show the total premiums collected for insurance to be approximately $183,000,000 for 1920, or about $20 per car. The State license taxes on car owners amounted to $91,000,000, or about one-half the insurance premiums paid, and the insurance companies paid back to the car owners $93,000,000 on losses. Taxes paid by the insurance business to cities, States and the Federal Government represent about 5½ per cent of their income. It is estimated that in 1920 the insurance companies as a whole broke even on liability, property-damage, collision, theft and fire insurance, although certain branches did not do so and it had to average up. All of the companies writing collision insurance in the metropolitan sections undoubtedly lost money, although the insurance was sold at what seemed to be prohibitive rates.

Relation of Design to Insurance

Assuming a car that the public demands, very little, if anything, can be done from the viewpoint of automobile design to prevent the accidents which are covered by the liability policies. When driving at night in Chicago I sometimes think that if I had a different windshield I could see better. I have a sedan car with a blind spot when turning a corner. I do not know whether others have had the sensation of turning a left-hand corner and finding that they were pivoting on a car they did not see. Possibly the question of blind spots, from the driver's viewpoint, and whether to use a straight or a slanting windshield are items that designers should take into consideration.

One would assume that the first thing a designer should do is to put good brakes on a car, but I know of owners who are obliged to turn the front wheel against the curb to hold the car on a hill. It ought to be possible to design a brake that will not freeze and that will hold the weight of the car on a hill. One firm thinks that a brake-lining should have a coefficient of friction of 0.40 and another company thinks that a 0.14 friction coefficient ought to be good enough. If an engineer designs car brakes for 0.40 and the purchasing agent orders a brake-lining having 0.14 friction coefficient, will the latter be as effective when it is installed?

The question of liability-insurance cost depends largely upon the ideas of the public or a jury as to whether a car owner is to blame because he is rich and whether the insurance company should pay because it is rich. It depends also upon whether the public considers automobile driving as a speed performance and never stops, never looks and never listens. The driver has the greatest control over the liability cost. Formerly a verdict of more than $5,000 for death was unusual in the settlement of liability cases. Probably as a result of the Government's guarantee to the overseas forces of $10,000 in the war-risk insurance, a verdict of $10,000 to $20,000 for the death of a single person is not at all uncommon today. This is an added cost in public-liability insurance and likewise an added reason for purchasing insurance.

Property-damage is very much the same as liability insurance except that the latter has to do with injury to persons. If one runs into a store window or another man's car, and one cannot fix the blame on the other person, then one is liable and the property-damage covers the liability. What one has to pay depends upon the ideas of the courts and juries. Usually the policy is for $1,000, but I would recommend to some car drivers that their property-damage policy be increased; the jury may think one can pay a larger amount and award it. There is much comfort in $1,000; it will pay for many lamp-posts, but when one hits a high-priced car, one wishes that his property-damage policy were larger. For the $1,000 the insurance company will try the suit. The car driver has perhaps more influence on the losses paid by the insurance company for property-damage than any effort of the designer.

Schedule Method for Automobile Fire-Insurance Classification

Prior to the adoption of the schedule method by the National Automobile Underwriters' Conference for 1920 business, automobiles were classified for insurance purposes according to the list prices established by the automobile builders for their products. These list prices were divided into groups or classes arbitrarily, and rates or premiums were quoted for each such group or class varying inversely, although not proportionally, with the average list price in each class. During recent years automobile builders, like most other manufacturers, found

it necessary to increase prices. Not infrequently these price increases have been sufficient to transfer a line from one list-price classification to the next higher. In the case of one popular automobile the list-price changes from 1917 to 1920 resulted in advancing its classification according to the list-price method by two steps, although no material modification in the chassis or engine design or in its acceptability from the point of view of any form of insurance coverage had been made. These changes resulted in a rate decrease of 46 per cent. Assuming policies written on new cars for the respective full list-price values in each case, the combined fire and theft premium decreased $8.65; the liability increased $1,340, while no material consideration accrued to the insuring company. There is now in process a reversal of this situation which will result in list-price decreases with revised list-price classifications and increased rates for lessened liability and no material change in hazard. That the automobile owner and those serving him were complacent as regards the insurance cost with the automatic lowering of rates from list-price increases is by no means a guarantee of similar broad and smiling satisfaction with the shoe on the other foot.

The fire risk in automobile coverage may be resolved into three principal components. These are the exposure hazard, with the garage risk as its chief item; the moral hazard; and the hazard of design, assembly and equipment of the automobile itself. Of these three components the moral hazard is not measurable by schedule and because of mobility the exposure hazard can be specifically analyzed, if at all, only in the rough. These components, either severally or collectively, must be averaged and be reflected in a basic or key rate, modified by flat increases or decreases for territorial, economic or other conditions as experience or expediency may dictate. Observe that the automobile builder may not control in any measurable degree, through list price or through construction items, the loss ratio established by his line from these exposure and moral components of the risk. Deferring for later consideration the remaining component of the fire risk, we find the collision hazard likewise comprised of three components: the driver or occupancy hazard, which may be called a moral hazard; the exposure hazard of traffic or territorial conditions; and features of design, assembly and equipment of the individual automobile or makes of automobile. A very brief analysis is sufficient to show that, as with the fire risk, the first and second components of the collision hazard are not capable of detailed analysis as to make of car, and must be averaged through a basic or key rate with flat increments of credit or charge for territory and for psychologic influence according to experience, expediency, or both combined. As to the fire risk, these items are beyond the automobile builder's control.

It will have been observed that the third component of the fire and the collision hazards is identical, being the features of design, assembly and equipment of individual models or makes of automobile. It is this component that can be specifically analyzed and which is almost completely within the builder's control. It is for this common component that schedules are employed.

The procedure in developing the schedules was substantially as follows: All items of design, construction, assembly and equipment thought to have the slightest bearing, favorable or otherwise, upon the hazards being classified were listed. Following this, items related were grouped and weights were assigned to each group indicating their approximate influence on the total share which the physical features may have of the total hazard. During the entire development period the advice and assistance of adjusters and automobile underwriters were sought and secured. Frequent conferences were had with committees representing the automobile industry whose cooperation in the work of development of the schedule has been an important factor in its success. It was at the request of the Insurance Committee of the National Automobile Chamber of Commerce that, to avoid the implication of a manufacturers' liability under subrogation or other action, the schedules assume a practical car with a minimum of safeguards and record credits for desirable features.

Reviewing first the fire schedule, we find that 85 items are employed to measure the extent to which a given model of automobile may be preferred as to fire risk over the assumed car with the minimum of safeguards. These items are grouped in sections or subsections as follows:

Sec. 1. Fuel Storage
- Subsections (1) Tank capacity
- (2) Tank location
- (3) Tank construction
- (4) Tank mounting

Sec. 2. Fuel-Feed System
- Subsections (1) Gravity feed
- (2) Pressure feed
- (3) Vacuum or pump feed

Sec. 3. Fuel Line and Fittings
- Subsections (1) Tubing and connectors
- (2) Gages
- (3) Strainers
- (4) Shutoffs

Sec. 4. Carbureter

Sec. 5. Electrical Equipment
- Subsections (1) Wiring materials, installation, connections, supports and protection
- (2) Devices
- (3) Circuits

Sec. 6. Exhaust Line
- Subsections (1) Position
- (2) Muffler and muffler cutouts
- (3) Exhaust heaters

Sec. 7. Miscellaneous and General
- Subsections (1) Mud-pan
- (2) Oil or gas lighting
- (3) Workmanship, stability and salvage

The classification schedule provides some 8000 points of credit for a thoroughly safeguarded automobile job as compared with the assumed practical job with the maximum hazard or minimum safeguards. This range of 8000 credits provides an enlarged scale, as it were, and compares in its limits with the range in loss ratio shown by the 1918 statistics of the National Conference for some 30 makes of car for which net liabilities were listed in excess of $1,000,000. With such minimum net-liability involved it is assumed that the law of general average fully applies. Consequently, the exposure and moral-hazard components become a constant in the loss ratio and the range in loss ratio therefore reflects the influence of the built-in hazard. Having determined upon the constant for the exposure and moral-hazard components and combined with it a smaller constant to take care of a remaining possibly persistent hazard of self-ignition, a method of classification according to credits derived by schedule remains for determination.

It can be seen readily that by the use of the schedule an individual or specific method of classification is immediately possible and it is not inconceivable that such specific or individual classification or rating may be adopted eventually. Meanwhile it is entirely feasible to

utilize the skeleton of the list-price classification method with which the entire automobile insurance personnel is already familiar. The range of credits available under the schedule is split into classes as shown in Table 2.

TABLE 2—RANGE OF CREDITS AVAILABLE

Class Symbol	Schedule Credits
(For Passenger Automobiles)	
AAA	} available for
AA	} future use
A	5,000 or over
B	4,500-4,999
C	4,000-4,499
D	3,500-3,999
E	3,000-3,499
F	2,500-2,999
G	2,000-2,499
H	under 2,000

The automobile insurance world is accustomed to the use of alphabetical symbols in connection with the collision and property-damage and liability classification. Therefore, no new or unfamiliar methods or practices are required of it in connection with a transfer to the schedule method when similar symbols are provided to indicate rate classes for fire and theft.

Considering now the 10 fire classifications established, at least for the present, we observe according to Table 2 that of the 8000 credits possible under the schedule, a total of 5000 only is required for assignment to Class A. The remaining 3000 credits are held in reserve, as it were, in the expectation of improvements in car design and equipment for which rewards of AA or AAA classification are promised. The five principal classes, A. B, C, D, and E correspond respectively to the five list-price classes and symbols which have been heretofore employed. Classes F, G and H are in the way of being penalty classifications in view of a serious lack of the safeguards commonly found.

One further point covering the fire schedule, with which we have dealt at length since its principle is that of the collision schedule and possibly of others as well, is that the symbolizing of cars and the classification indicated thereby in no way interfere with or dictate rates. The rate for Class A or AAA may be 1.0 or 0.1 per cent. The range of rate between Classes A and B, or B and C, or A or AAA and H may be as wide or as narrow as experience, expediency or other considerations require. Similarly, flexibility in a given range can be had through flat increases or decreases in the basic or key rate to distinguish between territorial or other circumstances of the business.

Substantially identical methods of analysis have been employed in the development of the collision schedule. The following examples will illustrate how feasible is classification by schedule of items of built-in design affecting the collision losses. Such items affect the collision loss ratio either by assisting to avoid collision or in the way of reducing extent of damage should collision occur. Of the latter group is the matter of radiator location. A certain heavy-duty truck has its radiator at the dashboard some feet to the rear of the forward cross-frame member which guards the engine and the hood from puncture by timber, pipes, tailboards and similar objects on other vehicles. Accordingly, in substantially the proportion of radiator-damage cost to the total collision loss ratio for trucks, credits are given in the schedule for this design as compared with the usual one. Similarly, in passenger-car jobs, a protected location of the radiator or its absence is recognized in the schedule by credits in number to indicate the relativity of this safeguard in the total of credits available.

Design Factors of the Fire-Hazard

As to the automobile fire-hazard from the viewpoint of design, it has seemed to me that the automobile industry has overlooked the fact that there is current in a storage battery. A storage battery can deliver about 500 amp. on an instantaneous discharge, can unload a large amount of current in 3 or 4 min. and melt any piece of wire if there is a good short-circuit. Instead of using the double-insulated circuits, manufacturers have grounded the car frame, because that is the easier and probably the cheaper way. I have seen unsoldered splices in the head-lamp and other circuits, instead of bringing the wires back to the switch terminal. In every case we understand that the reason for varnish-cloth insulation is that it also withstands heat and oil. It is easy to wire a car so that the wiring will not be exposed to oil. Battery slop will cause this insulation to rot for 6 or 8 in.; every time the hose is turned on it, the insulation will allow current leakage and some day there will be a short-circuit bad enough to set fire to the wood in the body of the car. The electrical hazard generally is a serious fire-hazard of automobile insurance.

There are a number of things to avoid in laying out the exhaust line. In one popular car the exhaust line lies about ½ in. above the engine-pan and over it is the carbureter, which drips. All carbureters flood and overflow. The "V" of the V-type engine is an excellent trap for this overflow and when the engine backfires the car burns. This design defect has been taken care of in most cases by installing a drain in the "V."

The breather is a severe fire-hazard. Unless the engine is washed every day, the oil vapor from the breather collects on the engine and ought to burn the first time there is a backfire or short-circuit forward of the dash. Backfiring is one of the frequent causes of fire. When a cold engine is started, a backfire will ignite the gasoline fumes before they are blown away. Automotive engineers should be able to do away with this fire-hazard; marine engineers have done so because they have had to do something to eliminate the foul smell and dirt around the breather. If something could be worked out for an automobile engine to burn up the breather fumes and wet oil so that the cylinder-block would remain clean, adequate consideration would be due in the insurance classification.

One of the meanest problems is the storage of gasoline and I have no patience with engineers who ignore it. It is not necessary to worry about gasoline while it remains liquid; it is the gasoline vapor that causes the trouble. The use of the engine-pan is an unexplained mystery; I do not know what good it does, at least for city driving. I took the engine-pan off of my car and it runs just as well. This pan is another very substantial fire-hazard in the equipment of automobiles. In addition to the engine-pan some cars have a leather boot all the way back.

From the collision viewpoint, consideration should be given to whether the side frame-members are heavy enough; I think these have been made too light. For example, a Ford car having a bumper hit another car; the Ford car was not damaged much, but the frame horns on the car it hit were bent from 25 to 35 deg., necessitating a very mean and expensive repair job that spoiled the looks of the car permanently. Automobile bumpers are doing much good. I feel sure that one of them prevented a serious accident to my own family. I

approve of the modern practice of putting substantial tubular braces out near the front-spring horns, but on some the ends of the tube are simply stuck in and the splits turned over, so that they are liable to drop out when the car is running. If put in for rigidity, they should be properly secured.

The number of cases in which the drain-plug on the bottom of the tank is scraped off when going over country roads is surprisingly large. Sometimes conditions occur in driving where the rear-spring clearance is zero, and tanks drag on the ground. If the car is going fast, the tank is likely to be damaged.

THE DISCUSSION AT NEW YORK

J. S. MARVIN:—At Mr. Small's request the National Automobile Chamber of Commerce and the Society of Automotive Engineers appointed committees about two years ago to discuss the construction features of cars, because the Underwriters' Laboratories intended to work out a plan of grouping cars according to construction features rather than by list price, for determining the insurance rates on the various makes. The committees have had several joint meetings. One of the details that came up during the discussions is the matter of identification marks and whether it would be practicable to make it more difficult to obliterate them. I quote the present S.A.E. Standard for the maker's identification number[3] and following that, the engine-number Standard.[4]

> The Standard location for the car, chassis or frame number, whichever is used for identification, shall be on the outside flat of the right-hand frame-number, as far forward as possible. The characters, not less than ¼ in. high, shall be heavily indented in the frame side-member. When this location is inaccessible, it should be approximated. The use of attached plates in place of characters stamped as specified is not desirable because of the ease with which a plate can be removed.
>
> The Standard location for the engine number shall be on the crankcase proper, at the front end, as near the middle, crosswise, as practicable, and on top, if possible. Consideration should be given to accessibility in the completely assembled vehicle. If it is not possible to locate the number near the center at the front, that position should be approximated, preference being given to the right-hand side. The characters, at least ¼ in. high, should be deeply indented in the crankcase.

It will be noted that the only description of how the numbering shall be done is that the characters shall be not less than ¼ in. high and be heavily indented in the frame side member. At one of the recent meetings of these committees it was decided that steps should be taken by the Standards Committee of the Society to make the changing of these numbers more difficult. Requests for suggestions were sent to a large number of engineers and to car, frame and engine builders, and about 65 replies have been received. Inquiry was made regarding present practice and possible changes, three suggestions that had come up in our committee meetings being mentioned, not with the idea that the voting was to be confined to them, but for the purpose of encouraging further thought.

The first suggestion offered might be termed a checkerboard plan, involving casting a series of numbers on the engine or a plate; digits were to be drilled out and plugged and the drill run through into the engine casting or frame member to mark permanently the digit drilled. The system consists of a series of numbers reading from the top to the bottom, 1, 2, 3, 4, etc., and crosswise, the idea being to drill them out so that the number can be read. The next suggestion contemplated stamping numbers, preferably of the script type, into the frame or casting to prevent changing easily from one number to another. The third suggestion was to use a number cast directly on the casting. The great disadvantage of this plan is that defective castings would interfere with the consecutiveness of serial numbers. Still another thought was to stamp numbers deeply into the frame or casting with a thin knurl, to make it still more difficult to change the number impression. This plan received considerable approval. About one-half of the replies recommended continuation of the stamping process, which is practically the present S.A.E. Standard so far as the type of numbering is concerned. One suggestion is that several parts other than the engine and the frame bear numbers, and that a record be kept of such numbers on each car. Unless all the numbers were located and changed, identification of the car might still be possible.

Speaking directly for the National Automobile Chamber of Commerce, it is our thought that it is very well to try to prevent the theft of cars but as long as there is a ready market for stolen cars and as long as there is a great incentive or, to say the least, no objection on the part of car owners to having their cars stolen or burned up, the answer to this problem will not be found. A friend told me recently that his new car last year was insured for $2,600 at a cost of $33.80. This year his bill for renewal shows that he is covered for $2,500 at a $55 premium. He said he would gladly take $2,000 for the car. Not long ago we learned of a number of cars having been found in Lake Erie, near Buffalo; six more were found in a quarry in Illinois. A police officer noticed recently the top of a touring car sticking up out of the water in New York Harbor and had it fished out and traced to the owner who said it had been "stolen." Such things undoubtedly are going on because of the high coverage. We doubt very much whether the insurance companies should cover cars to the present extent. One thought is that not more than 75 per cent of the value of the car should be written and in that connection possibly the depreciation should be provided for as cars get older.

The moral hazard has been increased very greatly during the last two or three years. It is likely that, within that period, many people have owned cars who could not afford them. Regarding fire, we seldom hear of a car that burns up in a densely populated district; the fires usually occur in some isolated spot. This seems to be significant. In our opinion insurance companies should appreciate the fact that in writing automobile insurance they are dealing with a different problem than when writing other forms of insurance. An automobile is an article that can be made away with very readily. The methods that have been applied, in other lines, of writing insurance for anyone for any amount he wishes, will not do at all for automobile insurance. The selling of stolen cars must be made difficult and the incentive for having cars stolen, the owner's indifference, must be eliminated by reducing the coverage, before the real solution of the problem will be reached.

CHAIRMAN H. W. SLAUSON:—The automobile insurance underwriters themselves maintain a detective bureau. Harry M. Shedd, director of that bureau, will now describe the methods employed by the underwriters

[3] See S. A. E. HANDBOOK, vol. 1, p. K41.
[4] See S. A. E. HANDBOOK, vol. 1, p. A13.

in recovering stolen cars and in apprehending and prosecuting the thieves.

HARRY M. SHEDD:—In February 1917 five companies saw fit to combine in an endeavor not only to prevent the theft of cars in some degree, but to make recovery by way of salvage. The bureau formed has grown until it now represents the entire membership of the Eastern and New England Underwriters Conference, composed of about 106 insurance companies operating in the United States and Canada. One of the first things done was to install a complete card-index system. When a car is reported by a member as having been stolen, an effort is made to ascertain whether the car number is correct. After we have been satisfied as to this, we send the number to the factory on a card prepared for that purpose and all component part-numbers are filled in there. These component part-numbers are cross-indexed. The names of the assurers also are alphabetically arranged. In addition, the car numbers and the engine numbers are numerically arranged. Whenever a stolen car is found by the police, even if both the engine and the frame number have been removed, we are able to ascertain at once the true engine and factory number of that car when we refer to the master index-card on which all the numbers are recorded. We are getting splendid cooperation from police departments throughout the country, and we are attempting to furnish information that will lead to the apprehension and incarceration of the thieves. But we are handicapped. We have an abundance of laws. What we need is judges who will, rather than parole prisoners, send them to jail for the moral effect. A great number of cases are brought to court by police officers who have worked tirelessly on them, apprehended the thieves and secured confessions, but the magistrates parole the thieves.

Our statistics show that less than 1 per cent of the total number of cars recovered by our men and also of the cars recovered by the various authorities throughout our district, have approved locking devices. In other words, the thief travels the line of least resistance and takes cars that are not locked. Many owners leave their cars thinking that they will be absent only for a minute or so and that it is not worthwhile to lock them. Thieves who wish to steal cars watch where the owner goes and it is within the first few minutes after a car is parked that it is stolen.

No two thieves work alike; organized gangs and many "master" minds are at work. Since our bureau was organized we have had only five cases in which there was some doubt whether the lock had been picked. One of the great troubles we have is our inability to get proper numbers from factories which fail to keep component-part-number records. Many car builders are efficient in this respect. They furnish quickly all information, by telegraph, telephone or letter, which makes possible the identification of a car. Others keep no records and, when we have visited the factories and attempted to find through our own search the whereabouts or the legal owner of a car that they have shipped, we have found this impossible. I believe that the standardization of a secret engine number, which it would be impossible to eradicate, is the solution of the matter so far as the identification is concerned.

The ignition lock is unsatisfactory. Some firms will even go to the extent of having Yale locks with 200 key-changes. They think this is a sure safeguard against theft, but all that is necessary is to open a closed circuit or to close an open circuit, and any car can be driven away within a few minutes by thieves. But we find that they will not take time to pick a lock which would make the car inoperative or at least give some trouble.

The apprehension and conviction of thieves would seriously interfere with the traffic in stolen cars, especially if the thieves were made to talk. It is true in some respects that the insurance companies are to blame largely for writing insurance on questionable cars, but it must be taken into consideration that, when the price dropped in automobiles, the cars that were insured for a fair market value then went to a premium; the people who wished to sell them, finding that they could not sell them otherwise, sold them to the insurance companies for practically what they paid for them. It is my contention that an insurance company cannot consistently make a complaint against an automobile, because at the time the theft occurs the insurance companies have no official stand in the matter. The complaint is against the State and the owner is not entitled to collect the claim until the matter has been turned over to the insurance company. I believe that the insurance companies should not make the complaints, for the simple reason that they are not interested parties until after the claim has been paid. Although they are interested financially and may ultimately have to pay the claim, the title does not pass to them until the claim is paid. If there were no market for stolen cars, if the stolen-car market could be destroyed and a penalty imposed which would be more severe for the receiving of a car than for its theft, the theft of cars would certainly decrease. The United States Department of Justice has been very active lately in the apprehension of thieves and prosecution where interstate-traffic theft has occurred; this has curbed the theft of cars to some extent. Our experience has taught us that the theft of cars from garages where the locks are picked, occurs where a person has all night to take the cars away, but these cases are rare. When a car is placed in a garage and the owner insists that the car be left unlocked, the dishonest employe has a chance to make a wax impression of the key and await his chance to steal that car. Further, we find that the thieves take out license-plates several days ahead of the day the car is to be stolen, and have the particular car they are looking for registered after the theft occurs; or they can go to the Secretary of State's office and give whatever number comes to mind, and have that particular number put on the engine of the stolen car.

Bills of sale do not mean much for the reason that if they are not properly inspected there is no law for the punishment of the people who issue fraudulent bills of sale, unless they do this knowingly. The notaries all hide behind the statement that they did not know the car was stolen and that they have only acknowledged the signature. In that connection we have found that the automobile thief is usually very friendly with some particular notary, which makes it hard to prove that the man who received the car knew he was purchasing a stolen car. We issue an alarm sheet daily that covers all of the cars stolen, but unfortunately these give only one manufacturer's number. That is because people who have cars insured do not give the insurance companies the proper number; whereas they should give both engine and frame number, they only give one. We attempt to ascertain whether this is the engine or the frame number but, even in the case of cars that bear both the frame and engine numbers these are sometimes transposed and several days are lost in finding out what the number referred to is.

Formerly when a man went in to report to the police that his automobile had been stolen, they made a note of it and promptly forgot it, but that condition is changing. Most cities are organizing police squads that devote their entire attention to the theft of automobiles. These men become efficient and can identify stolen cars quickly. The difficulty for both the police departments and our bureau lies in the fact that the owner will not equip his car with a suitable approved lock. In many cases, unless the lock is very easily operated and can be readily reached, the owner will not lock his car at all. If all cars were locked and the owners could be educated to keep their cars locked, the theft hazard would be reduced materially.

MR. O'HANLON:—When I was engaged in the building of cars, after getting out a somewhat elaborate system of identification marks we finally came to feel that this was a matter for someone else to take care of and that after we had put a number on the car our duty was done. I think that is more or less the idea among builders today and as a result the thief has little difficulty in removing all means of identification from a car.

In the case of one Hudson car that was recovered 11 of its 13 identification numbers had been removed. One identification mark consists of a washer. This has a number, known to us, on it. After discs like it have been placed in various parts of a car it is practically impossible for a thief to remove them all without taking down the entire car; because their number varies from 5 to 15; otherwise he would never be certain that he had found all the washers even though he might have found several. In addition to this disc identification service, we furnish a plate which is placed on the radiator for deterrent purposes. The plate is removable, but I know of nothing that cannot be removed from a car. It serves the same purpose as the detective-agency notification plate over a banker's window and was prepared, authorized and approved by detective agencies that are affiliated with us. Another advantageous feature of this identification system is that it is automatic in action, and one does not need to lock his car.

The question often arises as to the inspection of cars and the proving of ownership. An automobile title insurance company, affiliated with the company I represent, is now in process of organization. Its work will be to appraise and make physical inspection of cars, to determine whether any numbers have been changed. So far as the insurance companies are concerned, they can insist upon proof of ownership. This would eliminate many of the troubles of police departments and other officials engaged in the recovery of stolen cars.

A. R. SMALL:—In testing a lock submitted for classification we make a bench test or a driving test, as the manufacturer of the lock may prefer. We first consider the method of operation of the lock, and then ask the manufacturer to state for what makes or types of automobile he proposes to sell the lock. We receive many kinds of gearshift lock that are not suitable for some car models. It is useless to consider a free steering-wheel lock for a car which has 3 to 5 ft. of the steering column, not the outside enclosing case but the real steering post, exposed in the driving compartment. It is easy to steer such a car by using a stillson wrench.

We assemble the lock on a bench or in a car in substantially the manner it is designed to be operated. In the case of locks equipped with Yale-type keys, our first effort is to remove the locking cylinder. Very frequently that can be done with a ½-in. cold chisel and a ½-lb. hammer. After about six knocks into a gray-iron casting one can take off the whole cast-iron housing around the cylinder, withdraw the cylinder and then manipulate the locking bolt with one's fingers or with a screw-driver at will. A locking cylinder must be housed in a material of sufficient elasticity, ductility and strength to resist such ready and easy attack. Very frequently the lock cylinders are retained in place by set-screws. We have had locks from which when mounted on a small vibrating machine and operated for a few minutes, representing perhaps 3 or 4 miles of riding on a rough road, the set-screws would back out and the locking cylinder fall out.

Certain types of lock employing Yale keys can be broken into or picked with an ordinary screw-driver. The tumbler-pins inside the cylinder may be spaced so that perhaps only ⅛ in. of one pin is actually locking the whole bolt. By putting in a screw-driver or taking a pair of gas-pliers and getting hold of the real rotating member of the lock and cylinder, one can shear that locking pin off. Very frequently the submitter of the lock claims that the work has been done expeditiously or more easily because of the bench assembly; then we request him to submit an automobile with the lock mounted in it and proceed to defeat the lock in substantially the same manner as in the bench test. It is not feasible to explain in exact terms what our procedure is, because locking devices all differ, one from another.

Practically the first lock to be put out in any great number was a loose steering-wheel lock for Ford cars. It seemed to be a good thing but was soon shown to be ineffective because thieves were stealing the cars. In the steering mechanism of the Ford car there is a pinion in the spider hub that drives what looks like a planetary-gear system. The locking device withdrew this center pinion from engagement with the outside gears and held it out of engagement by means of an ⅛-in. steel washer. Investigation showed that the thieves were tapping the nut on top of the Ford steering mechanism with just a light blow of a hammer; in perhaps 60 per cent of the jobs they would succeed in dishing the washer sufficiently to permit the center pinion to engage about ⅛ in. with its gears and thus steer the car. We now require that this particular washer be made of a different grade of material, so that it cannot be bent so readily and we have kept that feature in mind in connection with every subsequent lock that is submitted. Our regulations are to the effect that it should not be possible to get away with a car under its own power in less than 20 min. with the tools available to an ordinary garage mechanic or one of our own engineers. That is not a very serious test if one considers how much an expert mechanic can do to an automobile in 20 min. The tools used are an ordinary 2-lb. mechanics' hammer, a cold chisel not exceeding ¾-in. edge, screw-drivers of any size, gas-pliers, ordinary pliers and a small stillson wrench; usually we can drive a locked car away in 20 min. with that apparatus. However, this all involves an opportunity on the part of our engineers, prior to the test, to study the locking mechanism and consider the methods of operating the car. One popular make of car that is very frequently stolen is being equipped with a factory built-in lock. It is rather a good lock and would impress many engineers and insurance company officials favorably. Our engineers studied it from the viewpoint of the operating mechanism of the car itself and not as a lock. It is a gearshift lock. In studying the mechanism and the way of operating the transmission and the effect of the application of the lock to it, we found that it was only necessary to lift the floorboards from the car and to make a certain shift with a

screw-driver of the shifting fork through a hole in the transmission case cover; whereupon the car could be put in first speed and driven away. A transmission working in first speed does not seem effective to the automobile engineer or the factory man, but the thief can get the car around the corner, drive it possibly ¾ mile and get it into some abandoned stable or a friendly garage. To drive a car in first speed for 20 to 30 min. is nothing to a thief, considering the reward he expects to get. If a thief knows the mechanism of a car and has an idea how the locks work from having gone into a dealer's store and looked them over, he can discover how to use the gearshift to get the car out of the way. I have heard stories of cars being driven from ferryboats up steep hills with the storage battery in emergencies. That is one way of defeating many of these locks. The destroying of a storage battery means nothing if the thief gets a $5,000 or a $10,000 car. We require further that the lock of the car shall be operable from the driving compartment, because it will not be used frequently if located elsewhere.

JOHN G. PURDIE:—I wish to bring up the matter of cooperation from the State authorities with regard to licensing, to which I have given much attention. Regarding the effort to have the second-hand-automobile dealers placed on the same basis as the pawn-brokers, that would be a very useful thing. In the State of Maryland the law requires that a traveling deed to the car shall be held by the owner. This matter of State legislation can be appreciated better when it is remembered that in the case of real estate bought for $50 the law requires stringent regulations to be observed with regard to obtaining title to it, registration and the like, but that no precautions are required with regard to a mobile piece of property worth perhaps $10,000. Any policeman or State officer in Maryland can demand the title deed to a car if it is registered under the law of that State, and if a car driver cannot produce it he will be locked up until he does produce it; so, we do not lose Maryland cars very frequently.

The registration system in New York State is practically useless for the purpose of recovering stolen cars. A record of the license number is kept in the office of the Secretary of State, but when a specific license number is inquired for about 10 days or two weeks is likely to elapse before the name and address of the owner of that car is furnished. Pennsylvania has a triple registration system which is very efficient. The car is registered under the make, the engine number and the owner's name. If one wants to know about a car and its owner in Pennsylvania, the Secretary of State's office can furnish the information quickly. These things are very important in the matter of making it more difficult for the thief to dispose of stolen property at any price and that is the most effective deterrent to the commercialized stealing of automobiles.

RICHARD COLEMAN:—During the 1921 Automobile Shows at New York City and Chicago I took up with a number of lock manufacturers the matter of an educational campaign. We have been told that practically only 1 per cent of recovered stolen cars were found locked; generally it is the unlocked car that is stolen. There are many good locks on the market that have withstood severe tests but the main point is one of education. Any salesman of automobile locks knows the truth of the statement that the average man who is insured does not care whether his car is stolen or not. I think that this attitude on the part of the average owner has been responsible for the action of the National Automobile Underwriters Conference in placing a $15 penalty premium on all insured cars which do not have an approved lock; and raising that penalty to $25 in New York City this year. It is simply a question of forcing people to lock their cars. I am firmly convinced that if the Society of Automotive Engineers, the National Automobile Chamber of Commerce, the Motor and Accessory Manufacturers' Association and the Underwriters would institute an educational campaign to "lock your car," car theft would be eliminated to a very large extent.

CHARLES J. EVERETT:—Although we have heard much about the stealing of cars and the methods of protection, it seems to me that we have not arrived at any definite conclusions that put us in a position to take effective action. I agree with those who say that locks, although something of a deterrent, will not stop the stealing of cars. I believe that we must obtain changed legislation in all the States, because changing it in one State alone will do no good; and further that the penalty for purchasing a stolen car should be made so heavy that it would act as a very great deterrent. Some legislation should be put through in the form of requiring an absolute clearance deed from the Secretary of State; if a man buys a car that does not have the original number on it or if the car number cannot be verified, he should be subject to a very heavy fine and should forfeit the car. Some definite lines of action should be determined with the idea of getting the matter eventually through the legislatures. If it becomes known that we are trying to take legislative means to stop the stealing of cars, that will be something of a start even though it may fail.

R. H. GOODWIN:—It has been intimated repeatedly that the insurance companies are not doing all that they can do to cooperate with the police departments and the general public in reducing this theft evil. The National Automobile Underwriters Conference represents substantially all of the stock insurance companies doing automobile insurance business in the United States, and I have had opportunity as its assistant secretary to follow very closely all of the legislative and other work that has been accomplished by its several committees. Unfortunately, we cannot do all that we would like to do because the business is subject to the various laws of the several States. The insurance business is peculiarly susceptible to State supervision. Each insurance commissioner has certain ideas that he thinks should govern the conduct of the business in his particular territory; few of them have the same viewpoint. That is, perhaps, one reason why the Conference has failed in some instances to adopt and enforce its uniform standard forms and practices.

The Conference has not been unmindful of the growing theft evil that has been discussed so much here this evening. As evidence of that fact it was announced to the general public, through the insurance papers, that as of May 1, 1921, the so-called valued form of automobile policy would be discontinued. We feel that this was one long step in the right direction. The car owner is more likely not to pay a premium on an amount of insurance in excess of what can be reasonably construed as the intrinsic value of the car at the time of loss.

The Chicago Crime Commission recently called upon the insurance agents in Chicago to cooperate with it and do something to reduce, if possible, the tremendous increase in thefts there. At that time we drafted a new form of theft policy, or an endorsement to be attached to the present theft policy, that provided for the exclusion from the coverage in its entirety of any liability for the

theft of tools, repair equipment, engine meters, spare tires, extra tubes, rims, ornamental fittings and other accessories. We went a step farther and made it a condition of the policy that the liability of the company for loss or damage caused by theft should not exceed 75 per cent of the actual amount of loss sustained.

Mr. Marvin stated that he thought the insurance company should not write more than 75 per cent of the value of a car. This particular form of policy is operative today in Chicago, and in Cook County, Illinois. It is on trial there, but it has not yet been adopted elsewhere. The business of an insurance company is to insure, and it is maintained by many that the insurance company cannot accept a man's premium for a certain amount of insurance and then pay him a less amount when he has a loss. The business of automobile insurance today covers against loss of or damage to automobiles; but the same companies are dependent for their principal income upon the regular commercial fire insurance lines which, in most instances, are their main lines of business. The automobile insurance business has been handled as a sideline from its inception up to the present by many of the companies. In many instances the insurance companies took on the automotive coverage to protect their fire insurance interests among agents who said that they must have every kind of protection that the public demanded. As a result, a few companies started an automobile insurance department, but it was treated more or less as a side issue. Automobile insurance has now achieved a prominent place in the insurance world.

The Eastern Automobile Underwriters Conference recently adopted a rule whereby it is mandatory for owners whose automobiles are not equipped with an approved locking device, to pay a $25 penalty charge in the boroughs of Manhattan, Brooklyn and the Bronx, New York City. The companies do not feel that tremendous increases in rates is good business. If the cost of insurance is increased to such an extent that it becomes virtually prohibitive, the companies will have practically ruined their business. We are beginning to feel that it is no longer a question of the rate and that something else must be done. The owner of the car must be made to realize that he has an interest in his insurance and an obligation to the public. Possibly this 75-per cent loss clause that is being tried out in Cook County, Illinois, may accomplish this. We are watching the results there with much interest. However, I wish to emphasize that the insurance companies, through the National Automobile Underwriters Conference, are certainly very much alive to the situation and, if it is at all possible to bring about the results we all want to attain in some other way than by increasing the cost of insurance, we want to find that way; but we want to be sure that we have found it before we put it into effect.

ETHELBERT FAVARY:—I speak from the automobile engineer's standpoint. The use of numbered identification washers placed at various parts of the automobile seems to me to be inefficient. When a police officer stops an automobile, how can he look for those identification marks? Of course, there is no way of marking an automobile to preclude entirely the possibility of obliteration, but some means can perhaps be devised to make this more difficult. I wish to mention a method by which a police officer could identify a car very quickly. It consists of raised letters on the water-jacket. Supposing those letters were ½ in. high, hollow on the inside, and that the jacket wall were 5/32 in. thick, and that the hollow part of the letters projected 3/16 in. beyond the outside of the water-jacket, it would be difficult to obliterate such marks, and one could tell whether the outside of the jacket casting has been patched or defaced.

In regard to proving title, I suggest that when a car is first sold the factory's bill of sale be a document on which the builder places his stamp, and that then the police department or a branch of the State department be required to stamp the bill of sale to confirm it. This same document should accompany the car at each transfer to a new owner. When the car is sold the owner should present that same document for stamping by the State or police officials; in this manner anyone could tell where the car came from originally and trace its ownership. If such a method were adopted it would, I believe, be very difficult for a thief to dispose of a stolen car.

M. C. HORINE:—In matters of this sort, as in medicine, we are apt to treat symptoms instead of causes. The prevalence of car stealing is a symptom of a cause which is a mental attitude and has been referred to as the "moral hazard." The moral hazard consists of an attitude of mind on the part of the general public, those who are charged with the enforcement of law and those who are charged with the interpretation of the law. In the early days of this Country the horse was regarded as one of a man's most useful and valuable possessions and the horse-thief was regarded as the lowest of criminals; so much so, I believe, that more men were lynched for horse-stealing than anything else. On the other hand, now that the automobile has replaced the horse in our civilization and such low beings as car thieves have appeared, they are regarded as rather clever; we would like to have them as mechanics, because they are so ingenious in circumventing the efforts of the lock inventors. The general public regards the car thief in nothing like the same light that our forefathers regarded the horse-thief. I think that this is the crux of the whole situation. We cannot get at the solution of this problem by locks because, as in military science, we find that there is no gun so powerful that armor or fortifications cannot be devised to resist it, and by that same principle there is no fortification or armor so impregnable that a gun cannot be found to pierce it.

What we need is, in the first place, just legislation dealing with the car-thief; a public sentiment, fostered by education, that will insist that jurists mete out justice to these offenders; and legislation that will make it possible to establish the ownership of a car. Insurance against car-theft as it exists today is only an aggravation to car thievery.

ADRIAN VAN MUFFLING:—One of the speakers mentioned that under present conditions it is impossible to raise the rates, but that it is possible to put a 75-per cent loss clause in the policy. It seems to me that this is the same thing. Paying 75 per cent of the actual loss sustained really amounts to raising the rate 33⅓ per cent, does it not?

EDMUND ELY:—We must consider two hazards; the interior hazard and the exterior hazard. The first is the hazard of the owner himself, what we in the insurance business designate as the moral hazard. The second is the subjection of the property to depredation by automobile thieves. The interior hazard, to my mind, is by far the greatest factor in the theft situation today. We recognize that certain palliative measures, such as locks and the stimulation of police activities, will remedy the situation to some extent, but in the face of an economic condition such as we are now experiencing it seems to me that nothing else can be expected than a very marked

increase in automobile thefts. We have a very unique situation. Notwithstanding any care that may have been exercised by underwriters in the underwriting of automobiles, last fall we had an automobile market that was all shot to pieces; reduction followed reduction. We are now experiencing a recurrence of the same thing and we do not know how far it will go. No matter what may be done by underwriters or how much care and foresight may have been exercised, I think we cannot be charged with negligence in not foreseeing that condition. With a piece of property insured for $2,000, if the bottom drops out of the market and the owner of particular piece of property knows that he can get only $1,000 for it and it is insured in such a manner that no active measures are necessary on his behalf to protect that piece of property, he is likely to have an accident; the theft experience is directly due in a very large measure to that condition.

I do not wish to convey the impression that the insurance companies generally are not appreciative of the good work that has been done in these alleviatory measures, such as the perfecting of locks and various other devices, but there are only two absolute preventatives of theft. First, the interior hazard can be cured only by assuring to the insured that in the event of loss by fire or theft he will recover only the actual market value. The incentive for him to be careless with his car will thus be destroyed. He might just as well sell it, because he cannot recover from the insurance companies any more than he could sell it for. The other measure is an absolute transfer of title in the same manner that realty is transferred. I do not say that this is advisable. I do not know whether it is the proper thing to surround traffic in automobiles with such restrictions, but it is the only thing that can absolutely destroy the marketability of the article and prevent thefts from the exterior hazard.

Apart from the unsettled condition of the automobile market, the bane of the insurance business is the over-insurance of cars. While I have commended the insurance companies in the face of the adverse conditions that existed in the past 12 months, I cannot but conceive that there may have been some laxity in that particular, and perhaps the experience that we are now undergoing will have a salutary effect in correcting it. However, I wish to have it borne in mind that the insurance business is in no wise different from any other commercial business. In the face of strenuous competition it is possible that the insurance companies may have over-stepped the boundary somewhat and no doubt there has been competition between insurance companies on the basis of the amount of insurance that they would be willing to grant; but it may be within your knowledge that even in the automobile trade it has been charged that while the members have an agreement to maintain list prices and would not reduce them, still they would allow an exchange of twice the value of the traded-in cars. The two situations are more or less analogous. Admitting that there are conditions that are detrimental to the welfare of the business, still we are unable to prevent them. Of all people the underwriters do not want high rates. We realize that when rates increase to such an extent as they have increased in automobile insurance, the very fundamentals of the insurance business are attacked. That is something we must avoid at all costs.

LEON OTTINGER:—I believe that any information which will assist the insurance companies to decrease their rates of insurance will be welcome. A young man in my office who owns a car had a slight collision. He had the manufacturer give an estimate of the cost of repairing the damage. The estimate was $85. The insurance company sent their adjuster to examine the car, and the owner was told that the repair would cost $350. It was discovered that an estimate for this amount had been submitted to the company by a son of the adjuster. The owner was exceptionally honest, and gave the information to the insurance company. If the insurance companies would make sure that their repairmen and adjusters are thoroughly honorable, they might be able to reduce their rates.

MR. SMALL:—It seems to me that we are going through a period in which we are all looking to law and to government for help. About 45 per cent of the suggestions that have been made here for curing automobile theft have referred to the passing of laws and asking the police or some other body to do something.

W. E. KEMP:—What measures do the insurance companies employ to compel the users of automobiles to lock their cars and how do they know whether the cars were locked or unlocked when they were stolen?

MR. SMALL:—I do not understand that there is any compulsion on the part of the assured to use the lock, other than the moral compulsion to observe the requirements of the locking-device endorsement in the conditions of his policy, to give it due diligence and care. What chance would an insurance company have to get a favorable decision from a jury, in case of attempting to refuse payment on a loss because the owner forgot to lock his car? No company will attempt to refuse to pay the loss because the car was not locked or the lock was not used, because the American public and the usual jury are against the insurance company and for the car, or the property owner, in every instance. Educate the automobile owner to put a lock on his car, to watch his car and not to leave it in places where it ought not to be. It is simply a matter of education all the way through and not one of the law or anything else.

THE DISCUSSION AT CLEVELAND

Mr. SMALL: The statistics show that closed cars are not being stolen as much as open cars. About 147 different makes of passenger car are listed by the insurance companies, and about 35 makes represent 95 per cent of the insurance liability. In other words, the output of the builders who are producing 9 or 10 cars per month does not affect the insurance records. After a car is four or five years old thieves will not take it. There was formerly a market in making such cars over into trucks. The statistics indicate the approximate loss ratio and cars are put into the classes to which they seem to belong, the rates being determined by the record for the preceding year.

One automobile builder that keeps an accurate card-index of the different identification numbers, claims that it costs $40,000 per year to maintain it. Many automobile factories do not attempt to keep such a record. One of the things that has been considered is a superior method of identifying cars. With a set of numbering tools, a cold chisel and a light hammer the number on a car frame can be changed to any number desired. Some numbers are on a brass tag. In many cases the serial number on the engine is in ⅛-in. figures stamped on the casting; it is easy to remove this with an emery wheel and put on a new number. I told the National Automobile Chamber of Commerce committee that I refused to admit that serial numbers could not be put on so that it would be practically impossible to obliterate them with-

out evidence of the marking having been defaced. The insurance companies have offered a reduction in the rate against theft of about 7½ per cent for a standard acceptable method of numbering the frame or the engine. We will not accept the first thing that comes out; it will be sent to the police departments and their experts will try to defeat the system.

K. B. BRITTON: There seems to be a rate on liability insurance according to the make of the car.

Mr. SMALL: The companies are still trying to rate the cars according to list price.

A MEMBER: Does the year the car was built have anything to do with the rate? Is the rate based on the original list price of the car?

Mr. SMALL: A large percentage of new drivers drive new cars. The whole matter of liability is one of insurance actuary methods; it is bookkeeping and accounting.

A MEMBER: Is any allowance made on account of the design of the brakes?

Mr. SMALL: No, our schedule requires at least two independent braking systems. More fires are caused by brakes on the transmission than by brakes on the rear wheels; they lock more easily and are close to the floorboards.

A MEMBER: Is any reduction made for having brakes on all four wheels?

Mr. SMALL: No.

A MEMBER: Do pressure-feed gasoline-tanks cause any difference in rate?

Mr. SMALL: Yes; everything else being equal, the rear tank with vacuum feed is the best and the pressure feed is next. No credit is allowed for gravity feed.

R. J. NIGHTINGALE: An insurance agent told me that theft is the starting point of practically all losses. If a car is found burned up, the most likely reason is theft; if there is a collision or property-damage, it usually can be traced back to theft.

A MEMBER: Do any cities have an ordinance requiring cars to be locked?

Mr. SMALL: I believe Detroit has one, but it is not enforced.

A MEMBER: In connection with design, has it not been the habit of designers to do away with metal toolboxes?

Mr. SMALL: I think we have not considered that.

Mr. NIGHTINGALE: The insurance man I referred to said that if the theft of cars were cut down by engineering, much money could be saved. One of our officials pays about $100 per year for $2,500 insurance against fire, theft, and property-damage; but I pay $130 on my car on a $1,200 valuation.

Mr. SMALL: If a certain car were insured against everything, it would cost about 70 per cent of the price of a new car for the first year's insurance.

Mr. NIGHTINGALE: One man has the same kind of a car as mine and lives in an adjoining county; he pays less than half the premium I pay and drives in town as much as I do. That is unfair.

Mr. SMALL: If every individual situation were investigated, the cost to all would be prohibitive. It is necessary to make an arbitrary rule.

GENERAL STATUS OF TECHNICAL EDUCATION

A SUMMARY of the registration statistics for the years 1919-1920 and 1920-1921, as compiled from the reports of 81 engineering colleges located in 36 states, presents some interesting facts. It will be noted that, with respect to the total registration, all courses except chemical engineering showed a gain this year over last. In the case of the freshman registration, on the other hand, a loss is shown in every instance. During 1919-1920 the freshman registration amounted to 43.8 per cent of the total college registration, while this year the freshmen were 37.4 per cent of the total number of students.

TABLE 1—SUMMARY OF RETURNS FROM 81 ENGINEERING COLLEGES, SHOWING BOTH TOTAL AND FRESHMAN REGISTRATION

Course	Total Registration			Freshman Registration		
	1919-1920	1920-1921	Gain or Loss	1919-1920	1920-1921	Gain or Loss
Mechanical	11,693	12,159	+ 466	5,089	4,607	— 482
Electrical	11,285	12,118	+ 833	5,487	5,089	— 398
Civil	8,469	8,592	+ 123	3,612	3,046	— 566
Chemical	6,588	6,486	— 102	2,652	2,249	— 403
Mining	2,252	2,431	+ 179	903	786	— 123
Miscellaneous	6,018	6,526	+ 418	2,614	2,302	— 312
Total	46,395	48,312	+1,917	20,357	18,073	—2,284

The figures as summarized in Table 1 show that mechanical engineering is the most popular course in our technical colleges. This year 12,159 students were registered in this specialty and last year 11,693, a gain of 466. Electrical engineering runs a close second, the figures for this and last year being respectively 12,118 and 11,285, or a gain of 833. Civil engineering comes third with 8592 undergraduates this year and 8469 last year. Chemical engineering, with about 6500 students for the past 2 years, takes fourth place, while the mining engineering course, in fifth place, shows a considerably smaller registration than any of the others, 2431 this year as against 2252 last year. A reference to Table 2 indicates the percentage relation of the registration in the several special courses to the total and also the freshman percentages.

TABLE 2—PERCENTAGE RELATION OF SPECIAL COURSES TO TOTAL AND TO FRESHMAN REGISTRATION

Course	Per Cent of Total Registration		Per Cent of Freshman Registration	
	1919-1920	1920-1921	1919-1920	1920-1921
Civil	18.2	17.8	17.8	17.0
Mechanical	25.2	25.2	24.7	25.6
Electrical	24.3	25.1	27.1	27.8
Mining	4.8	5.0	4.5	4.3
Chemical	14.2	13.4	13.1	12.5
Miscellaneous	13.3	13.5	12.8	12.8
Total	100.0	100.0	100.0	100.0

FOURTEEN PASS 1000 MARK

Fourteen of the colleges are giving engineering instruction to 1000 or more students. The highest registration figures are reported by the Massachusetts Institute of Technology, Cambridge, Mass., with 2747 students. Next in point of size comes the University of Michigan, Ann Arbor, Mich., with 2212; third, Purdue University, Lafayette, Ind., with 1845; fourth, Cornell University, Ithaca, N. Y., with 1825, and fifth, the University of Illinois, Urbana, Ill., with 1818. The other nine institutions above the 1000 mark are, in order of size, as follows: Ohio State University, 1473; University of California, 1323; Georgia School of Technology, 1307; University of Minnesota, 1284; Pennsylvania State College, 1233; Texas Agricultural and Mechanical College, 1169; University of Wisconsin, 1150; Rensselaer Polytechnic Institute, 1039; and Iowa State College, 1011.—*Engineering News-Record.*

Lubrication of Timing-Gears

By E. Planche[1]

Illustrated with Photographs

THE tendency to simplify the design of engines has led a great many designers in the past few years to lubricate the timing gears with oil coming from the crankcase, instead of using a separate system of lubrication for the gears. This practice is

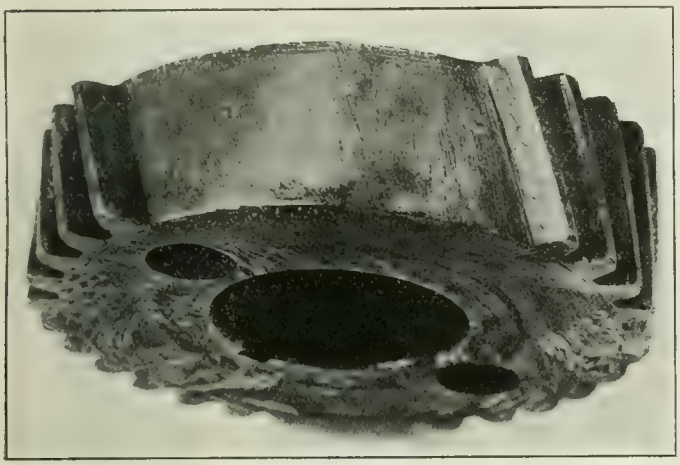

Fig. 1—A Crankcase Gear That Was Lubricated with Crankcase Oil as It Appeared After Running 10,000 Miles

very commendable in itself as it permits the car owner to lubricate the engine bearings, the cylinders, the pistons and the timing-gears by the simple operation of filling the crankcase with oil to the proper level and letting the engine do the rest of the work.

I used this system on an engine four years ago, to replace a system of lubrication of timing-gears, using

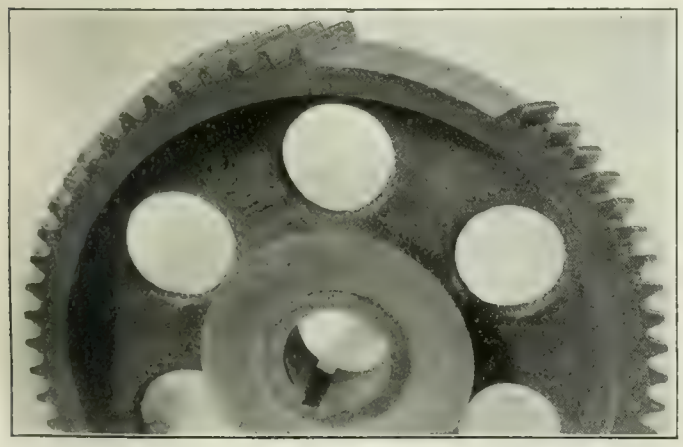

Fig. 2—This Camshaft Gear Shows a Very Uneven Wear on the Face of the Teeth After Running 10,000 Miles

heavy transmission oil in a closed gear-case. At the time that change was made it was commended almost unanimously by dealers and owners as a step ahead. However, a year later, when the cars using that system had been driven long enough to permit making com-

[1] M.S.A.E.—Chief engineer, Dort Motor Car Co., Flint, Mich.

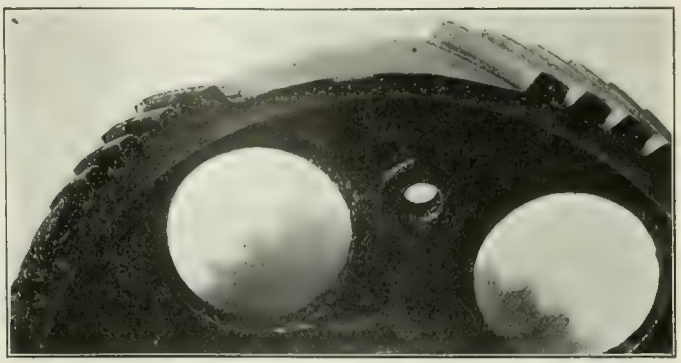

Fig. 3—A Camshaft Gear That Was Run 17,000 Miles with Heavy Oil as a Lubricant Showed Much Less Wear Than the Gear Illustrated in Fig. 2

parison with the older cars using the heavy-oil lubrication for the timing-gears, dealers complained that the new engines were noisier than the old ones, and that complaint has been chronic since, growing steadily as the quality of gasoline kept declining. As I analyzed the complaint, the cause of the noise was the excessive wear

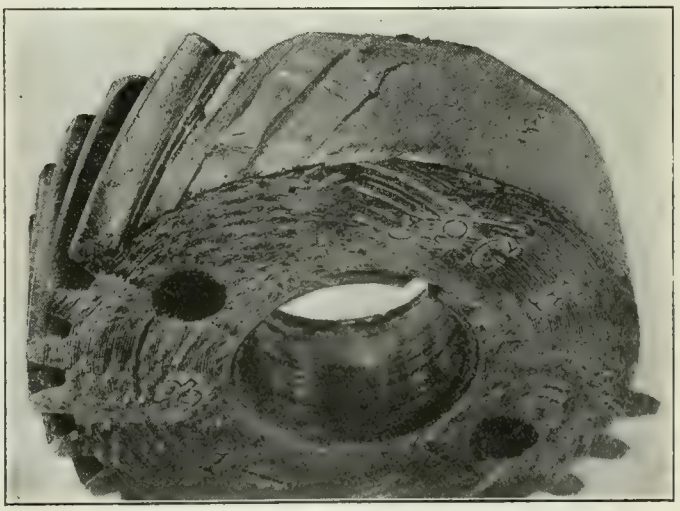

Fig. 4—A Heavy Oil That Was Entirely Separate from the Crankcase Oil Was Used to Lubricate This Crankshaft Gear and the Backlash After Running 17,000 Miles Was Only 0.002 In.

of the gears and a rough condition of the tooth face. The cause of the wear is the poor lubrication received by the gears. The cause of the poor lubrication is easily traced to the use of oil with little lubricating value left. It is well known that all our present engines show a decided dilution of the crankcase oil, in daily use. This dilution is more pronounced in the high-speed types of engine than in the medium-speed types, but is present in all engines. It is more noticeable in cold than in warm weather, due to the longer time necessary to warm up the engine in winter. Such diluted engine oil is very thin and dirty and has very poor properties as a lubricant for the timing-gears.

I measured the wear of the set of timing-gears illustrated in Figs. 1 and 2, which were taken from a four-cylinder engine using crankcase lubrication that had run 10,000 miles, and found that the back-lash of the gears, which was originally 0.002 in., had increased to 0.018 in. On a four-cylinder engine of a different make the back-lash had increased from 0.002 to 0.016 in. in 8000 miles. The wear of the face of the teeth was very uneven, indicating a continuous pounding of the teeth against each other with very little lubricant between them. On the contrary, gears taken from engines using the heavy-oil lubrication in the gear-case show very little wear and a smooth tooth face, and the engines run much more quietly. This set of gears is shown in Figs. 3 and 4 and the difference in the amount of wear can be readily seen by comparing these illustrations with Figs. 1 and 2. The back-lash in this instance is only 0.002 in.

The conclusions to be drawn seem to be that an independent system of lubrication of the timing gears with clean and preferably heavy oil, with no connection whatever with the crankcase oil, is far better than the present system of using the crankcase oil.

FARGO TRACTOR DEMONSTRATION

THE report of the farming demonstration recently conducted by the National Implement and Vehicle Association at Fargo, N. D., is of interest since it gives average fuel and lubricating-oil consumption in terms of acres for a group of 36 tractors of various types and sizes. The tractors were required to plow, prepare the seed-bed and seed a total of 360 acres. The average plowed was level and covered knee-high with weeds, the soil being black gumbo.

TABLE 1—GENERAL AVERAGES OF ALL TRACTORS

Operation	Plowing	Preparing and Seeding
Kerosene Tractors		
Gasoline Consumption per Acre, gal.	0.120	0.094
Kerosene Consumption per Acre, gal.	3.010	1.250
Lubricating Oil Used per Acre, gal.	0.110	0.040
Man-hr. per Acre	0.940	0.418
Gasoline Tractors		
Fuel Consumption per Acre, gal.	2.770	1.280
Lubricating Oil Used per Acre, gal.	0.050	0.030
Man-hr. per Acre	0.950	0.430

The general averages of all tractors qualifying in the demonstration are summarized in Table 1.

TABLE 2—TRACTORS WITH CHEAPER FUEL

Operation	Plowing	Preparing and Seeding
Gasoline Consumption per Acre, gal	0.102	0.105
Kerosene Consumption per Acre, gal.	2.870	1.160
Lubricating Oil Used per Acre, gal.	0.095	0.040
Man-hr. per Acre	0.950	0.420

Other averages were secured for tractors whose fuel costs were lower than the general average of those given in Table 1. These are included in Table 2.

The six tractors whose fuel costs were lowest, based on Fargo prices of 11.8 cents per gal. for kerosene and 23.1 cents per gal. for gasoline, gave the results presented in Table 3.

TABLE 3—TRACTORS WITH MINIMUM FUEL COST

Operation	Plowing	Preparing and Seeding
Gasoline Consumption per Acre, gal.	0.041	0.034
Kerosene Consumption per Acre, gal.	2.510	1.010
Lubricating Oil Used per Acre, gal.	0.080	0.020
Man-hr. per Acre	0.840	0.320

HORSE RESULTS

Five horse outfits competed with each other and independently of the tractors in the work of plowing, preparing the seed-bed and seeding 10-acre plots. The average feed costs for horses are given in Table 4.

TABLE 4—FEED COST FOR HORSES

Hay Used per Outfit, lb.	352.00
Oats Used per Outfit, bu.	13.85
Man-hr. per Acre Plowed	2.64
Man-hr. per Acre Prepared and Seeded	1.43

These results are based on written reports of observers who checked the work of each horse and tractor outfit, and were compiled by the Supervising Observers Committee consisting of H. H. Bates, chairman; E. A. White, president of the American Society of Agricultural Engineers; Prof. J. B. Davidson, Iowa State College, representing agricultural colleges, and O. W. Young, representing the Society of Automotive Engineers.

THE POUND STERLING

OVER the greater part of the world the rate of exchange on London normally is an accurate indication of the trade balance. The price of the pound at New York City is a way of expressing the value of American goods that the pound will buy there. Normally it will buy $4.86 worth but when the British demand for American goods is urgent, competitive bidding by British merchants or bankers inclines them to pay more and more for the goods, in other words to take less and less for their pound.

In periods of normal trade movement the price of the pound at New York City rarely moved outside the limits of $4.84 to $4.89½. At $4.84 or below, it was cheaper for the Briton to buy our goods with gold than with a pound's worth of goods; therefore at $4.84 gold would leave London for New York City. At $4.89½ or higher, on the other hand, the Briton would not take our goods; they were too high; he would send a pound's worth of his own goods and get $4.89½ of our gold; with that $4.89½ worth of gold the Briton could buy more goods elsewhere than he could get from us. Therefore at $4.89½ or higher gold, not goods, would leave New York City for London. So smoothly did these processes work that for more than 30 years before the war the highest price of sterling exchange at New York City was $4.91, the lowest $4.82.

It is a remarkable fact that at most other financial centers the pound is selling at a premium. In 28 countries sterling is above normal parity in 20 and below normal parity only in the United States, Holland, Canada, Sweden, China, Japan and Switzerland and at Hongkong. The reason for the discount at New York City is a very simple one. The war created an enormous demand for our goods, which were shipped abroad to a much greater value than foreign countries could pay. These transactions were financed in a large part by the United States Government, which loaned to foreign countries nearly 10,000,000,000 American dollars to enable them to pay for these goods. As long as the American goods were paid for by these American dollars, the price of the pound at New York City was not controlled by the value of the goods moving from our shores, and it was possible for government control to "peg" it at $4.78. Shortly after the armistice this government support was withdrawn and the pound once more stood upon a competitive basis. All other foreign currencies are selling at a discount in New York City; not one of them is at par.—A. W. Kimber in *Michigan Manufacturer and Financial Record.*

Comparison of European and American Automobile Practice

By Maurice Olley[1]

New England Section Paper

THIS paper is presented more as a record of impressions than an accumulation of facts and figures. It will be confined to passenger cars and as far as European practice is concerned, to England and France, which can be taken, I think, as representative of the two schools of automobile development in Europe, France representing Continental practice, while English motoring has developed along lines to suit its own peculiar conditions.

Perhaps it would be well, as a beginning, to look at the difference between the automobile industry in Europe and in America, and then consider briefly the reasons for the difference. The American industry is turning out large quantities of cars on a purely commercial basis. Its mind is concentrated on the ultimate consumer, who it appears to believe rules it completely. The French and English builders are not in this position to the same extent. They do not produce cars in such large quantities, but each supplies a strictly limited field with a specialized product of some individuality. The profits of past years have not been entirely reinvested in enormous increases of plant and equipment and therefore they are at no time as securely tied to the market as their American brethren. The only quality that their products must possess to sell is that they shall transport passengers on the road with some degree of reliability and considerable speed. Beyond this requirement, there is absolute freedom. Here, on the other hand, every builder of vehicles, except motorcycles, must make something that has all the qualities of the traditional automobile; it must have an engine of at least four cylinders, almost necessarily water-cooled, with the conventional arrangement of accessories under the hood, a clutch and three-speed gearbox and the customary propeller-shaft to the differential and live axle. Of course, it must have four wheels and a top or covered body, and the wheels even must be 56 in. apart, no more or no less, a truly crippling state of affairs as far as design is concerned.

Differences in American and European Conditions

In connection with the reasons for the differences of the industry and design of cars here and in Europe, in the first place motoring here is transportation, pure and simple. It is rapidly becoming the most important system of transportation in the country. In Europe, leaving aside the recent vast increase in trucking in England, the automobile is not transportation but adventure. A man mounts his 3-hp. motorcycle in England with the feeling of a knight-errant. Here he jumps into his four-door sedan as one boards a street car. This one fact is of the utmost importance in automobile design. One explanation of it might be that there are about 10 or 15 times as many cars here per capita. I think this may be an effect rather than a cause, the car being so essential to transportation here that a vast number were produced, while the car was so unessential in Europe that it remained a rarity.

Probably the great reason for motoring being a commonplace here is the higher standard of living that brings a car within the reach of almost everyone, whereas in Europe it is still almost a luxury. Again, in Europe the better roads, the more attractive and historical countryside and the more merciful climate enhance the pleasure of motoring. At the same time the commuting difficulties that curse the wage-earner in this country, for some reason do not exist in Europe. All these causes contribute toward rendering the car in Europe a vehicle of considerable romance, not merely a daily drudge or a common household appliance.

A very important factor in the European automobile world is the cost of owning a car. The first cost, as compared with that of the United States, is difficult to determine, because of the reduced value of money and the difficulty of assessing the true value of cars. It will be best probably to take prewar money equivalents, since the value of money decreased about equally in Europe and here during the war. It appears to be approximately true to say that a car will cost twice as much in England as in the United States in proportion to living standards, and in France almost twice as much as in England.

In England gasoline costs about 80 cents per imperial gal. (65 cents per United States gal.) and in France, from 12 to 15 francs for 5 litres ($2 to $2.50 per United States gal.) Tire prices have apparently declined in England even more than in the United States. In prewar days tires there were about twice as expensive there as here. Furthermore, whereas American makers understate the actual size of their tires, the European tires were far below their stated size. Perhaps, as a consequence of this, the European tires will not generally give anything like as good mileage as American tires of equivalent rating. As an example, the 895 x 150 mm. European tire, which should be about 36 x 6 in., is actually the close equivalent of the American 33 x 5 in. as regards both size and wearing qualities. Taxation of cars is heavy in Europe, particularly in England where the tax is now £1 per hp. per year, the horsepower being calculated from the cylinder diameter exactly as in America.

The fierce competition of the motorcycle in England at least, which is continually developing to get the small-car trade, is the third condition affecting the industry and design. The motorcycle is favored by the higher cost of gasoline, tires and taxation, the later average age of marriage, the habit of renting houses rather than buying them, with a consequent shortage of garage space, and better roads and weather conditions. I imagine that in England there are at least two motorcycles to one car. There are 7 firms building motorcycles in the United States as compared with 50 in England.

The automobile industry is limited by the lower standards of living, by lower wages and also probably by a higher standard of thrift. The limitation of the indus-

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try has reacted upon itself in enhancing the cost of cars. It remains to be seen whether Ford and the other American invaders can break down this obstacle to development. Another limiting factor is the distinct prejudice in the minds of many Englishmen against motorcars because they are an offense against the doctrine of "regular exercise." Many well-to-do city men living in London suburbs do not own cars to this day because the week-end is devoted to exercise of one sort or another, cycling, walking, tennis or cricket, and a car might break down these regular habits.

The design of cars is, of course, affected directly by climatic conditions, the open car being the popular model all over western Europe, and the top, or cape-cart hood, as it is still called, being an accessory, for use only in severe weather. Road differences affect design differently in England and France, the national highroads of the latter country, and perhaps the racial peculiarities of the inhabitants, making speed the one essential. Design in England is affected greatly by the essential democracy of its inhabitants or perhaps by the fact that there the car is not the standard of the man. Here a man will buy a car of cost proportioned accurately to his income or his pretensions. There a cabinet minister or railroad president will own a Ford sedan or take pride in the possession of a miniature vehicle peculiar to the country called a "light car" or voiturette and resembling a traveling bathtub. His social status is not governed by the car he drives, or by his income, but rather by the particular accent with which he speaks the English language.

Summarizing the conditions then, they are

(1) Spirit of adventure
(2) Cost
(3) Motorcycle
(4) Limited size of the industry
(5) Climate
(6) Roads
(7) Lack of definite money standards

Surveying these governing conditions casually, one can trace the effects with reasonable accuracy. The European motorist demands less convenience than the American. As an example, whereas the latter insists upon electric starting and lighting, even on a Ford car or a motorcycle, many European smallcar owners are content with electric light only, retaining hand-starting; and many small cars, and nearly all motorcycles, retain the old-fashioned gas lamp. The American user demands that the car give useful service with the minimum of skill in handling, whereas the English, and still more the French, owner delights in a car which will give maximum results in the hands of a skilled driver.

Cost affects the Continent and England differently. On the Continent, though many excellent small cars are being produced, the best efforts of the trade seem to be mainly directed to the larger cars, and the automobile trade appears to have made up its mind to cater to the rich principally. In England, on the contrary, the middle class is having its demands met by the cars that I have called traveling bathtubs. These little cars have been produced continuously in England since the earliest days but have always either perished, because their cost was out of proportion to their performance, or have gradually developed into larger and more pretentious vehicles. The small car appears to have come in with a rush in England and it seems that it will be the quantity-production car of the future in that and perhaps other countries. These miniature vehicles, complete in every essential, are excellent machines, from every point of view, for use where roads are good.

Motorcycles and Small Cars

The motorcycle is becoming an institution in England and is used by old and young, and by both sexes almost equally. On English roads and in English weather it is the perfection of motoring as distinct from mere luxurious riding. The machine weighs only 150 lb., is no bigger than an ordinary bicycle, travels 100 miles on a gallon of gasoline, and yet is capable of an average speed of 30 m.p.h. and a maximum of 60 m.p.h. It can never lose its place in the affection of the British motorists, 80 per cent of whom have probably served their apprenticeship on motorcycles. It is a fine training for driving a car.

There is no hard-and-fast line of demarcation between motorcycles and cars in England, except in the matter of number of wheels. All vehicles of four wheels, however arranged, are classed as cars and taxed at the rate of £1 per hp., while all vehicles having two or three wheels are motorcycles in the official eye and are taxed independently of horsepower at a flat rate of £4 per year with three wheels and £3 per year with two wheels. Accordingly, there has been a development away from the traditional motorcycle and side-car combination to a machine which is in all respects a small car except that it drives to a single rear wheel instead of the customary two-wheeled real axle. These vehicles, which cost not more than £300, are now of very good mechanical construction, and are entirely safe because they are hung low. They are fast and efficient, making 50 miles per gal. at speeds up to 45 m.p.h. The gradual development of the three-wheeled type would have been a severe blow to the carbuilders had they not met it with small cars of even greater mechanical merit which can carry two or four persons in comfort at high speed, with a rating not exceeding 12 hp. The upward movement of the motorcycle and the downward movement of the car have determined the typical present-day British car-type, coupled, of course, with the heavy burden of taxation and the high cost of fuel.

The limited size of the industry and of the individual manufacturers in Europe makes for higher cost, but for a more painstaking treatment of both the initial design and the finished article. It makes for a car of more individuality, a greater distinctiveness in each maker's designs and a greater receptiveness to designs that are highly unconventional. It is well known that where the output is restricted the product is likely to and may safely have more individuality than where the output is great. In other words, the design of the average European car is largely controlled by the engineering department, whereas the design of the American automobile is principally controlled by the buying public through the sales organization. In the main this seems to be the explanation of the great similarity of American cars as compared with European. Consequently minor points of individuality which would pass unnoticed in the description of a European car are emphasized in the American advertising, from which the public would assume that there were many points of design differing radically from those of other cars.

The climate is chiefly felt in body design. There is a positive prejudice against permanently covered cars, except in the most luxurious types. The top is still merely an emergency affair of waterproof canvas which is put up only for severe rainstorms. Wings and skirting panels are less complete than in America, and the protection

against mud and water is not nearly so advanced. Generally, the weather-proofness of the European cars is less perfect than that of the American vehicles.

In the mechanism of the car, the principal effect is that the control of the water temperature has not attracted so much attention as in the United States, and less care is taken on the average European car to insure an effortless start in cold weather. When night temperatures very seldom fall below 27 deg. fahr., a car designed solely for use in England and employing a fuel far superior to American gasoline need have little provision for forced vaporization. The Rolls-Royce practice of fitting a vaporizing primer and regulatable jets is very exceptional in England and entirely due to its cosmopolitan use.

Road Conditions

In England, even after years of neglect, the roads are excellent. The moist temperate climate keeps a water-bound macadam road in perfect condition almost forever without repair, as long as the traffic is not too heavy. However, the grades are heavy, the roads have simply grown rather than been planned, and hence there are few straight stretches and few easy hills. Most of the roads are narrow, the old coaching turnpike and the occasional vestiges of the old Roman "streets" being the only exceptions. Because of the hedgerows, blind corners and hidden crossroads are the rule rather than the exception and as a result handiness is essential. Cars must run well in high gear at all reasonable speeds and on all ordinary grades, and the brakes must be ready at instant call.

In France there are three sorts of road: the national highways, which are perfect motoring roads in every sense of the term; the secondary roads, which are the opposite, and the cobbles in the towns and villages, which are atrocious. The result is seen in the French cars where speed for the national highways is the first consideration. Roaring, noisy engines that will make 4000 r.p.m. without flinching for hours are demanded and the carbureters, which may or may not give flexibility, must be of the "straight through" type offering no obstruction to the inlet gas. Brakes, often on all four wheels, which will pull up a speeding car in a minimum distance are a prime requisite. For the by-roads and city streets, with unflexible carbureters, there must be four speeds, a powerful clutch-brake, an easy gearshift lever and plenty of slack in the transmission gears, so that the lever can be crashed over, up or down, at all speeds, without care or effort. There must be stiff springs and a sturdy framework, both for high speed and for city cobblestones.

The average Continental car on English byways is uncomfortable to drive and ride in, being rough and noisy and calling for continual gear-changing. On Continental roads it is in its element and shows to advantage if one is a courageous speed-hound.

American road conditions, now happily improving, have called for a car which can "go anywhere in high." Hence the low axle-ratios, large engines, small high-velocity induction systems, and other features which cause the typical American car to "waste its sweetness on the desert air" at all speeds above 25 m.p.h. The American car is the most convenient vehicle in the world to start and drive. It is best able to get any place whether there is a road or not and is the paradise of the lazy driver. It is year-round transportation with the minimum of grief, but it is not a speed monster. It is not pleasant to steer, with certain exceptions, and its brakes are deplorable.

Car Idiosyncracies

If an American has a car it must be a real car or at least look like one, and be of such a size that the human figure does not noticeably overlap the edges. Builders of the smaller cars, in the illustrations of their advertising matter, fill their cars with pigmies to enhance the impression of reality. To agree with the illustrations of my own car, I should not be more than 4½ ft. tall. The American buying public is assumed to have formed its standards. It expects, or so the builders assume, the same main features in a $1,000 as in an $8,000 car. In France and on the Continent as a whole the full-fledged car is generally for the rich and as such is complete and rather conventional and also distinctly expensive. There have always been in France voiturettes with one or more cylinders, but they have never been regarded very seriously and actually do not call for a full driver's license for permission to operate. In England there are no accepted standards of design. The only two standards of practice are speed and economy. Until recently there were many single-cylinder cars. Now these have disappeared, but an engine can have two, three, four five, six or eight cylinders; it can be air or water-cooled, horizontal, vertical, Vee or radial. The transmission can provide two, three or four speeds, or, as in a number of small cars, drive by friction discs and gears, or chains to the rear axle. Chain, propeller-shaft or V-belt, Hotchkiss drive or torque-tube, differential gear or none, rear axle or single wheel, all are acceptable to the buying public. The actual size and shape of the cars vary enormously. The three-wheeled vehicles generally have the single wheel behind, but at least one has two wheels on one side and one on the other. The track width of four-wheeled cars varies from 42 to 58 in. and the wheelbase from 80 to 150 in. The tire sizes on cars vary from 27 x 2½ to 35 x 5 in., and wheels may be wood, steel-spoked, disc or wire, the last being in the majority. Starting may be electrical or unassisted. Lighting is by electricity or gas. The ignition, however, is almost universally by magneto, but the battery is slowly gaining.

External appearance is uncontrolled and varies from the extremely dignified to the extremely weird, and from the utmost symmetry to an indescribable lopsidedness. Among the miniature cars, some most beautiful proportions are to be found, while many bodies fitted on large cars would attract jeering crowds in the United States. The reverse is equally true. England and Europe generally demand the full run of the spectroscope as regards color and trespass over the edges. To European eyes all American cars are black. Bear in mind that anyone may ride in the most peculiar or tiniest of these cars without loss of dignity, and it will be possible to see how free and untrammelled the scope of automobile design is in England.

Selling Conditions in Europe

Perhaps what I have already said will serve to show the conditions that American cars have to meet in Europe. American cars have sold and are still selling in Europe in large numbers, because they have a great reputation for reliability, and they can always be bought from stock, but they do not show to such a great advantage in Europe as in America. The reason for this is that their engines are, from the European point of view, too big for the performance obtained from the car. In other words, they consume too much gas. Table 1, giving the average specifications, will illustrate this.

TABLE 1—AVERAGE SPECIFICATIONS OF CARS

	American	English	Continental
Number of cylinders	6	4	4
Power according to National Automobile Chamber of Commerce Rating, hp.	26.00	13.80	15.50
Bore of Cylinder, in.	3.40	2.95	3.10
Stroke, in.	5.00	4.75	5.10
Stroke-Bore Ratio	1.45	1.60	1.65
Average Gage, in.	56.00	51.00	53.00
Minimum Gage, in.	56.00	42.00	40.00
Maximum Gage, in.	56.00	58.00	56.00
Average Wheelbase, in.	122.00	115.00	122.00
Minimum Wheelbase, in.	....	88.00	86.00
Maximum Wheelbase, in.	....	150.00	146.00
Axle Ratio, in.	4.50	4.15	....
Number of passengers	6	3	....
Weight of Chassis, lb.	....	1,800	....
Approximate Weight of Complete Car, lb.	3,000	2,300[2]	....
Price	$2,794	£610	....

[2] Many English cars completely equipped weigh from 1500 to 1700 lb.

In France a number of cars are developing on American lines. Unit construction, battery ignition, smooth external appearance, detachable cylinder-heads, left-hand steering and a host of detail fittings are making them appear more and more like American cars. They differ, in having greater speed and less high-gear flexibility, but better brakes. I cannot find the average price of Franch cars but imagine that the rate of exchange, import duty, etc., make competition from this side very difficult.

The American car probably is at a disadvantage in its quality of finish and the detail design of its mechanical parts, which have always looked rough-and-ready to the European eye. The lower maximum speed would count against it. Since on the Continent cars are only run by people of some wealth, the tax and fuel consumption of American cars are not insuperable objections. To judge by prewar experience, the smaller Continental cars are lacking in completeness, convenience and mechanical perfection. For example, the Continental designer has always appeared to lose patience when he gets to such details as the controls; accelerator connections, for example, are likely to consist of the fewest possible pieces of bent wire and to be proportionately unreliable.

The more interesting conditions exist in England. Here there has always been an admiration of the low-priced American cars, and from the first days builders have been striving to evolve a low-priced car for the English market. The "£100 car" has become almost a slogan. The failure to produce a really low-priced car has been largely due to the fact that English builders have not realized that a really good inexpensive car can be secured only by quantity production, and that it is a matter of capital and tools rather than design. The attempts at low prices have failed because they have "cut corners" in design and produced something which was either not safe or so unlike a real car as to be unacceptable even to the catholic taste of the country. Now with the heavy tax on horsepower and expensive gasoline the conditions have changed and the English builder should be able to meet American competition with a car that is, perhaps, a little more expensive than the imported vehicles in first cost, but much more economical to run, smaller, handier, equipped with better brakes, has a better external appearance and is generally more suitable to the local conditions. In this respect it is interesting to consider Table 2, taken from *Motor* (London), Jan. 12, 1921.

The ordinary American car even of the smallest class would be at least as expensive to run in England as the most expensive type quoted. It seems to me that England is on the point of solving its transportation problems in an effective manner. In view of the fuel consumption given, England apparently is achieving real fuel economy, and it becomes a question whether this country might not attempt to develop on similar lines. Surely, as a first step to fuel economy, it would be logical to reduce the horsepower of American cars by 50 or at least 30 per cent, leaving the axle ratio unchanged or even raising it considerably, and gaining flexibility by a reduction in weight and improved carbureter design and also perhaps by four-speed gearboxes. The objection might be made that it would be necessary to shift from high speed more often, but the English light cars only have to shift the gears occasionally in ordinary running conditions to judge by the reports of trial runs, unless exceptional grades are met, and the grades in England are very much worse than here.

Objections to a gage less than the traditional 56 in. are often heard. The first is that the car rocks sideways more with a narrow than with a wider track. I think this is not so on road surfaces where reasonable speeds can be kept up. The 7-ft. gage railroads in England were proved to roll more than the 56½-in. gage, and narrow-gage railroads show good riding qualities. The same argument applies to narrow-gage cars on decent roads. The objection that the narrow cars will not fit the ruts made by other cars on dirt roads or snow works both ways, I think. Personally, on a light car, I prefer not to have both wheels in the ruts at the same time. In the same way street car lines are safer for a car whose gage does not fit them.

TABLE 2—COMPARISON OF CARS

Size and Type of Car	Four-Passenger 16 to 20 hp.	Four-Passenger Small Car	Two-Passenger Light Car	Four-Wheel Cyclecar	Three-Wheel Cyclecar
Weight, lb.	2,800 to 3,300	1,800	1,600	1,350	Under 800
Tax	$75 to $100	$50 to $70	$50	$50	$20
Fuel Consumption per Year, Imperial gal.	250	200	166	110	85
Miles per Gallon of Fuel	20	27	30	45	60
Cost of Fuel per Year	$220	$160	$145	$90	$74
Miles per Gallon of Oil	500	700	1,000	700	700
Cost of Oil per Year	$25	$17	$12	$17	$17
Cost of Tires per Year	$150	$90	$75	$60	$50
Total Annual Cost	$465	$317	$282	$222	$161
Annual Cost per Person[3]	$116	$80	$140	$110	$80

[3] Figures are based on the assumption that full use is made of the seats. Since the four-passenger cars can be assumed to carry not more than two persons on the average, it is safe to double the cost per passenger in the first two cases.

Road conditions are certainly bad in the United States as a whole, but are rapidly improving, and in the Eastern States are becoming similar to the English roads. I believe that a light car of European design would perform very well on the ordinary roads of Massachusetts. a narrow gage would certainly not be an unmixed blessing in winter with its heavy snowfalls, but I think that a small car with a low bottom gear, not too much forward weight and a really good control of the rear axle, would push its way through most obstacles, particularly if the road clearance were kept fairly high by sloping the transmission and using small rear-axle gears. Four speeds would be almost a necessity.

Comparison of General Design

Many European cars are built around the engine and in fact in some of them the designer's interest appears to have waned after the engine was completed. This was a real failing of many prewar cars. A real attempt to raise the mean effective pressure in European cars, by increased compression, inlet-valve opening and induction systems is noticed. The valve-in-head engine is coming in slowly and generally is equipped with a detachable head. In at least one case of a detachable head screwed plugs are still used over the valves. This seems good, since with the detachable head, although the operation of cleaning the cylinder is made easier, there is far greater difficulty in making a quick inspection of the cylinder and valves than with the older type of non-detachable head with screwed plugs over the valves. Also, it is more necessary to inspect the interior of the cylinder when a detachable head is used, because of the danger of internal water-leaks. With the ordinary type of detachable head, when once the head is removed and replaced, there is a constant fear as to what sort of joint has been made, and the only way to find out is to detach the head again, and so on ad infinitum.

In a large number of valve-in-head designs the camshaft is on top, following airplane engine practice. The contrary school is still vastly in the majority, proving by excellent examples that a well designed L-head engine can be as efficient and as free from detonation as the valve-in-head. The two-cylinder horizontal-opposed engine is gaining much favor for light cars, this being a development of motorcycle design. Air-cooling is considered only for small cars, probably because the danger of freezing up is practically not existent in Europe.

Magneto ignition still holds the field in Europe by an enormous majority, but certain makers have been tempted by the excellent American battery-ignition systems to abandon their former practice, probably as a matter of justified economy. On small cars without an engine-starter the magneto is almost universal and seems correct, since in this way the car can always get home, battery or no battery. As long as an engine is free enough to be started by hand on the magneto, there is a real advantage in having one, as least as a second string.

The battery-ignition wires and apparatus extend over half of the car and a number of things are likely to happen to the wires and terminals in inaccessible places which may take endless trouble to remedy. In magneto ignition the only wires are the high-tension leads to the plugs, failures of which affect one plug at a time and are easily traced, and one ground wire which is sometimes omitted on European cars. The last, if it breaks, will not stop the engine but will prevent stopping it. Hence the European faith in the magneto, which will take a lot of shaking.

Clutches are about evenly divided between the cone and the plate types in Europe, whereas in America the latter is in a large majority. Perhaps this is accounted for by the excellent cone-facing fabrics which one can obtain in Europe and by the cheapness of manufacturing a plate clutch from pressed steel in America. In this Country it is necessary to have a clutch that will slip longer without burning, because of snow, and the multiple design is good in this respect, of course, but not better than a cone clutch with heatproof facing, which is more likely to remain cool than a pack of discs.

Gearboxes have four speeds on 80 per cent of Continental cars and 50 per cent of English cars, including a large number of the small cars. The advantage of four speeds, particularly on the small cars, is evident and might be considered, one would think, for America, if the public could be educated to it. For small powers the extra weight of a four-speed box is not great, and the speeds are needed. With a decent clutch and carbureter the car should start on second speed and climb most hills on high and third speed, but the first speed is good for emergencies. Gearboxes are being combined more and more with the engine on Continental cars, particularly the small ones. In England, however, the majority of gearboxes, all cars considered, are still independent and fastened to the chassis behind the engine, 70 per cent being mounted in this way. On the Continent about 50 per cent are attached to the chassis and 50 per cent to the engine, and the latter method is on the increase.

Some of the English light cars using two-cylinder engines of the horizontal-opposed type combine the clutch casing and gearbox with the crank-chamber in a very neat form, so that the entire working mechanism of the car is accessible by merely raising the bonnet. Gleason bevel gears are coming into use to a great extent, and are displacing not only the straight bevel gear, but also the worm which before the war seemed to be gaining favor rapidly. The Gleason bevel is undoubtedly one of the biggest contributions to automobile design since the Bilgram bevel-gear planing-machine.

Springs are almost always half elliptic on the front axle. At the rear, there has been a landslide to the quarter elliptic and cantilever, which were fitted on 70 per cent of the cars shown at the recent Olympia exhibition. The half-elliptic springs, so popular here, are fitted on less than one-sixth of the European cars, if we can judge by the recent shows. Since the cantilever spring implies some sort of effective control of the rear axle, the movement in this direction seems to be good. The torque-tube, or other axle control scheme, seems too short in many European cars, to be really good. In most of them it would have been possible to lengthen it considerably, with advantages in riding qualities and in holding the road. Some of the European cars retain the fork joint at the head of the torque-tube without any provision for a side movement of the axle, but most builders seem to realize that this is wrong and use a spherical or other universal joint. Generally speaking the one or two torque-tube designs which have recently appeared in the United States are far better than the general run of the new European designs, as regards both mechanical design and appearance.

Several of the lighter English cars omit the differential altogether, and drive either one wheel or both wheels through a rigid axle shaft. This practice does not appear to ruin the tires on a car of 2000 lb. or less, and is worthy of consideration in the United States because of its great advantage in mud or snow. America has

better tires at a lower price than Europe, which is an additional reason why it should consider dropping the differential on small cars.

American design seems to be at a standstill as regards brakes and the European design is almost without exception better. The good point about the American design is that both brakes are generally on the rear wheels, but this is neutralized in most cases by the lack of an equalizing device. The bad points appear to be that the external brake, which is relied on to do the work, is in effect little more than the old-fashioned strap brake, tried and abandoned on bicycles. It is likely to grab, is only approximately balanced, is unequal in its application, springs considerably before it really gets hold, is exposed to all the winds that blow and yet will heat up almost immediately. On very few cars does it ever really come free. The internal or so-called emergency brake is generally no more than an enlarged piston-ring and is best disregarded. The smell of rubber and burnt string on any American highroad hill in the touring season is sufficient criticism of the local brake design, and the columns of the newspapers are its condemnation.

The means of applying the brakes too often consist of bent wire and other things that spring, so that the driver cannot tell the moment at which his brakes make contact and simply keeps on pressing with his foot, in the hope that something will happen soon. When it does, it often skids the wheels because the bands after slipping for a time have grabbed. Brake facings in America do not appear to be equal in wearing quality to those used in Europe. The use of rods to the rear axle, instead of steel strip or cable, leads to rattling and frequent breakage.

One would imagine that the double internal-expanding brake so often used in Europe would be cheaper to manufacture than the general form of American band-brake, since it consists of fewer parts and is a machine job from start to finish. It is better because it is weatherproof, will not run so hot, is more definite in its application, and is better balanced and more readily adjustable. The side-by-side variety implies a wide drum, but a new type which has appeared lately, consisting of a single, width drum with four internal shoes, each working on a quarter of the circumference, and controlled, one pair by the pedal and one pair by the lever, seems to solve the trouble. Pressed drums can be used, but should be flanged outward on the inner edge for stiffness and cooling, and should be bored or ground to run true. Improvements on the lines suggested would form a great step forward in American cars.

Much adverse criticism of American bodies has appeared recently in the English technical press, but an examination shows that it applies wholly to the open touring bodies, to which I imagine American builders have not given much attention lately. Recent American open bodies have aimed too much at sporting lines to be comfortable. They are not deep enough and the seating is too upright. I think the designs which are now critisized in Europe came originally from Europe in a number of cases. Europe has, however, reverted to deep comfortable open bodies, such as were standard in this country before the war, using them all the year round and therefore demanding the utmost of usefulness and comfort.

This Country undoubtedly leads by a very large margin in detail finish of closed bodies and in accessories, and I cannot help feeling in general lines also. The recent developments in quantity production of closed coach-built bodies form another notable advance for which the United States is responsible, and the quality of workmanship and material in these closed jobs seems to be at least as good as much of the exclusive coachwork of Europe.

America proved that the automobile is not the monopoly of the rich, and is now showing that true comfort in the automobile is equally available to the man in the street. In other words, what the public wants, it shall have. The quantity production of coach-built bodies is a great step in advance not only because of low price; by quantity production coach-building is lifted from an art to a mechanical science. It has been shown that timber can be worked accurately to make interchangeable parts and like metal is capable of proper heat treatment and that results can be guaranteed. The individual coach-built body is often a nuisance to the manufacturer of the chassis and the owner of the car, because it is found frequently that in some particular the body work clashes with the mechanism of the chassis, or vice versa. By the quantity production of bodies such interference can be rooted out in the first experimental sets, electric wiring can be standardized and a whole host of minor annoyances thus be avoided.

In Europe the open car will probably always hold the field because of the difference in climate. Without doubt any form of covering for European cars will have to be truly collapsible. Perhaps America will now show that a really convertible job can be produced in quantity, which will not rattle and can be thrown wide-open in the fine weather and covered again by two persons in 5 min. European and particularly English closed-body designs appear to be going through a phase which one hopes will be temporary. The rear end of a number of English bodies resembles that of a sausage in general design. I refer to the excessively rounded designs that are so popular in England just now and appear so hideous to American eyes. In touring cars the European designs are almost uniformly good except that in some cases the desire for a disappearing hood has spoiled the lines of the car.

Sheet aluminum is used extensively in European body-work but the treatment is not as complete as in American bodies, and exposed wood joints are used in window-frames, which are likely to give trouble in the event of a change of climate. Aluminum roofs, used to obtain rounded designs previously mentioned, are not satisfactory in many instances as they tend to boom badly and they make the interior uncomfortably hot in summer weather.

Summary

As a summary, I wish to emphasize the following points:

(1) The use of cars is radically different on the two sides of the Atlantic, and selling points which are vital to the American public, such as engine-starters, transmission locks and service organizations, are of secondary importance in Europe

(2) The cost of running a car is greater in Europe and the roads are good; therefore cars are growing smaller, and it is the small car, above all things, which appeals to the general public, especially in England. If America wishes to hold a big trade in England, she must evolve small, fast, economical cars of the utmost refinement as regards mechanical parts

(3) American body-work, as known in Europe, is unsatisfactory. Actually American body-work, as a whole, is of a higher quality than the European.

It only remains for America to turn her attention again to producing comfortable touring bodies, for her to meet European requirements absolutely in this respect

(4) American brakes need an entire redesigning from the pedal or lever to the rear axle, if they are to meet European ideas. The idea of the hand-brake being an "emergency" brake must be eradicated. If it is to be used in an emergency only, the driver never accustoms himself to use it, and in an emergency it is never ready. It is immensely better to call it a hand-brake, make it adjustable for wear and build it for use. It only remains to train drivers to use it frequently on all long hills; it will then be used in emergency and may prevent a number of accidents

(5) Europe does not appear to know anything about detail design that is unknown in America. With the exception of the overhead camshaft engines, the small horizontal two-cylinder engines, the Argyll single-sleeve, the Ricardo trunk piston and one or two other items, every European design is reflected strongly in the United States

(6) If Amercia were to build light cars on European lines for export, I believe they would sell in large numbers in the eastern part of the United States, where road conditions are favorable to them. These cars must not be built for use in cities only however; they must have speed and capacity for touring equal to those of the largest cars built in this country

Except in the matter of their large size and horsepower the outlook for American cars all the world over appears to me to be particularly good, because the United States is now aiming at not only production but the production of high-quality designs. In recent American designs equal compression volumes are often insured by machining the heads; six-cylinder crankshafts have seven bearings and are finished all over in the circular grinding machine; pressure lubrication is used for all moving parts of the engine; and in all ways the highest practice is aimed at, combined with strictly mechanical methods. Other countries are trying to reduce costs while America, having done so, is trying to improve the quality without increasing the costs. It seems to me that it only remains for America to produce cars that are strictly suitable for European conditions, to gain a firm place in the esteem of European users. There is no doubt that having gained a place in the regard of the European public, American salesmanship and service organization will see that the place is retained.

THE DISCUSSION

V. A. NIELSEN:—Mr. Olley intimated that the English people do not look very much to service organizations. Will he please explain this point?

M. OLLEY:—They do appreciate service organizations, but they are not important as a selling point for a car. That was my meaning.

MR. NIELSEN:—Does this mean that service stations for taking care of the cars are not needed?

MR. OLLEY:—In this Country the service organization can be made a distinct selling point for a car. In England a better mail service is maintained, so that you can get anything over-night, and the fact that cars are not used daily makes the service organization of less relative value.

I. F. RICHARDSON:—Mr. Olley referred to the large number of Continental and English light cars. Does the same thing apply to the Italian field for the light car? And how is the Belgian field?

MR. OLLEY:—I can speak only of France and England from personal knowledge but I imagine that neither Italy nor France has a real field for the small car as it is distinctly an English product. This is a sweeping statement, because a number of small cars are being produced in both Italy and France. I think there are not many in Belgium. The Belgian roads are generally better than the French and the Italian roads as far as I have seen them. England is the most important market for the small car. For the Continent, generally, I think that it is only necessary to build a car that will travel fast, making its cylinder diameter as small as is feasible, for the sake of taxation, and having the induction pipe and the carbureter as "straight through" as possible.

A MEMBER:—How are the American motorcycles considered?

MR. OLLEY:—They are very popular in England and are going there as side-car machines. The average man who runs a motorcycle expects 100 miles per gal. of fuel. There is a general feeling that the heavy motorcycle is inconvenient and really an extravagance. The motorcycle is very often kept in the front passage, between the front door and the stairway, and it must be lifted up the stairs, which cannot be done very easily with heavy machines. The thing that has upheld the American motorcycles is their excellent rear springing, which commenced to count very heavily when certain roads began to be cut up by war traffic.

VICTOR W. DOW:—Is there a movement for standardization of sizes and dimensions?

MR. OLLEY:—The Institution of Automobile Engineers has done nothing of moment toward standardization. The very little amount of standardization that there is in England is regrettable. On passenger cars alone there are something like 35 different tire sizes between the dimensions of 27 and 35 in. In everything else, thread sizes, shapes of nuts, methods of locking nuts and in every particular there is a lack of standardization. However, as a measure of economy, standardization is coming in England. Whether it will come from France in metric sizes or from the United States, I do not know. The latter is making a great bid for the standards on tires, but France is making a big bid for the standardization of machine parts. The Metric Association in England is very strong, has gained membership rapidly and is trying to get everything reduced to metric sizes. All electrical work is, of course, in millimeters.

R. G. THOMPSON:—In general, what starting and lighting system is favored in England?

MR. OLLEY:—As far as I can see, in England the two-unit system is generally accepted. On all the big cars, an engine-starter is provided, but in the case of most of the small cars the starter is an extra. If a lady buys a small car, it is generally equipped with a starter. A man who has a small car will usually not bother to have a starter. He will most likely buy the car with a dynamo, and probably that is one governing factor in determining the use of the two-unit system. You must remember that the engines on the small 10-hp. cars can be turned over like a sewing machine. Bear in mind that the traffic conditions of the United States do not exist in England. If the engine stal's the driver can hop out and start it up again, and nobody will say anything or look nasty. Probably, if there are any traffic policemen around, one will come up and turn the starting crank, and in a country where it is possible to park at either side of the road

and in the middle, the mere delay of traffic is not regarded as an offense. It is probable that the very small cars will not be equipped with electric starters that would add perhaps 50 lb. to their weight; they are, of course, drawing the line very fine on weight. On the larger and also on the medium-weight cars, the starter is practically universal. The types of electrical starting and lighting schemes are not very many in England but they are developing very rapidly. A number of companies that engaged in the electrical business during the war are now turning their attention to starting apparatus. It is generally good, and finished better than the average American apparatus. It looks better on the outside but I think it could not do its work any better, because as far as my own experience is concerned, the average American electrical apparatus is practically perfect in service. Undoubtedly starting and lighting systems will be used universally on every car above 16 hp. and probably on 50 per cent of the smaller cars, but I think that for the sake of economy in the production of the car and in weight there will always remain a large number of very small cars in England and in France which will not be equipped with them, but they will all have a generator and electric lighting.

F. J. STONE:—Will you tell us something about the development of the commercial truck?

MR. OLLEY:—The most interesting feature of the truck in Europe is the very great development of the steam truck in England. It was developed for some War Office trials in 1898, and since that date it has not changed greatly in general form. Typically it consists of an old-fashioned traction engine, with the cylinders on top of the boiler, built into the forward end of a heavy wagon. The boiler is a miniature locomotive built for hand-firing with hard coal, and the engine an open-crank horizontal two-cylinder compound, with the crankshaft and flywheel at the rear end. The driving gear on the crankshaft drives a sliding-gear two-speed transmission, without the use of a friction clutch. It is, therefore, necessary to stop the engine to drop into the lower gear. From the transmission the drive goes by a long roller chain down one side of the car to a chain sprocket and differential on the rear axle. This is a live axle of apparently crude design, which, however, gives excellent service. Originally these trucks ran on steel tires at theoretical maximum speeds of 5 m.p.h. Now, however, they are almost always fitted with solid rubber or giant pneumatic tires, and make speeds up to 20 m.p.h. Since the start of the war trucks of this type have been built in England by probably a dozen firms, but they are not an innovation, having been in use in Lancashire for 20 years, transporting cotton from the port to the mills and back in very hilly country. They have gained a very secure place in England.

During the war the gasoline truck developed rapidly in England into a rather heavy monstrous but excellent machine, carrying generally about a 5-ton load. This type is now being produced in quantities in England. Another development is a self-feeding steam truck, looking more like the traditional automobile, using an ordinary hood with the boiler underneath.

Since the railroad strike in England long-distance trucking has been gaining enormously. During the strike all trucks were commandeered by the Government and the resultant improvement in the freight service, directly due to the railroad strike, was so remarkable that trucking is now on a very secure footing in England and the railroads on a correspondingly insecure foundation.

A MEMBER:—During the war a large number of the passenger cars were run with gas bags. Have those been abandoned?

MR. OLLEY:—That was artificial gas. Those have all been abandoned. I think they are not even permitted because of the danger of explosion, although the economy was remarkable, of course, as the gas cost only about 3½ shillings per 1000 cu. ft.; the cost of running was only about half the cost with gasoline.

A MEMBER:—What progress in the use of benzol is being made in England?

MR. OLLEY:—Benzol is accepted in England, universally, I believe, and it is preferred in France. Before the war benzol was being pushed by one or two of the automobile papers in England with the idea of breaking the grip of the gasoline trust. Mr. Royce used a large quantity of benzol in the south of France. We used it straight and also mixed with gasoline. Almost everybody was using it or trying it. Some people got foul engines, most of them got foul exhausts, and there was considerable disappointment. We put in a special float, I think that was all, to allow for the heavier liquid, and used it straight on the car in the south of France, for many months, with excellent results. The present position of benzol in England appears to be good. From what I can gather a large number of cars are running on a mixture of half gasoline and half benzol. Whether benzol will continue, I do not know, but at present it is an accepted factor, and I gather that most people are using it. In England we are providing for its use by making benzol floats and are already recommending customers to use a mixture, and in every way it is coming to be regarded as a standard. On big airplane engines it is considered necessary to use at least 30 per cent benzol to prevent detonation, and it is thought that by using a mixed fuel a bigger cylinder diameter can be utilized than with straight gasoline. The other development in Europe is alcohol, which is looked upon there as the probable final development of internal-combustion engine fuel. It is realized that oil will not last forever, and, as regards Europe, it is very difficult to procure. England, I believe, wishes to develop large tracts of land in Africa for producing alcohol. It has realized that benzol can be produced only in a relatively small quantity and will not replace the demand for gasoline, even as it exists at present. If alcohol can be produced and be made non-intoxicating, there is no doubt that it will be the fuel, probably in five years or possibly ten.

MR. NIELSEN:—Does benzol cause any deposit?

MR. OLLEY:—It probably does form a little more carbon than gasoline, but inasmuch as a large proportion perhaps of the carbon in the cylinder is road-dust, that does not make a very big difference. It was feared that some corrosive acid from the benzol might attack a steel cylinder, but apparently this is not so. I do not know whether it attacks aluminum.

E. A. COUSINS:—Mr. Olley, in referring to battery ignition, seemed to infer that the failure to be expected is in the wiring. In his opinion, is American wiring practice superior to that in England and in France?

MR. OLLEY:—I think that American wiring practice is very good. I do not know that I can say that England's trouble with battery ignition is due to failure of wiring, because few European battery-ignition systems have been marketed until lately, and, as far as I know, there have been no failures. All I meant to imply is that the European builder, regarding the simplicity of the one scheme, as compared with the complexity of the other,

has theorized and said that the magneto is practical and simple and that therefore he will stick to it. The consideration that the magneto does, to a certain extent, eliminate the necessity of providing an automatic advance, has led to the adherence to the magneto. Even in the case of motorcycles, where a large amount of hand adjustment is to be expected, the necessity of watching the ignition advance has led to a very great prejudice in favor of the magneto.

MR. COUSINS: — I have understood that tungsten breaker-contacts corrode rapidly in England.

MR. OLLEY:—We have been trying tungsten contacts and found that they corrode. I do not know whether that is due to the climate. I imagine that the climate might make a difference. Platinum contacts are still the standard in England. If tungsten contacts are found generally to give more trouble in England than they do here, we should be interested to know about it, because we are interested in any development in the use of tungsten or any other of the possible alloys. We are constantly in touch with and trying out all of those things, but at present we have not found anything to compare with platinum.

INTERNATIONAL COMMERCE

IN 1818, the entire volume of international commerce was only $2,000,000,000. In other words, after countless milleniums of life upon our globe, men had been able to produce only that relatively modest volume of world-exchange. And, for several decades thereafter, increase was not portentously rapid. In 1850, the volume of world-trade had grown to only $4,000,000,000. Between 1850 and 1900, world-trade increased five-fold to $20,000,000,000. This increase was astounding enough, but it was nothing compared with what was to follow. For the first decade of the twentieth century witnessed an absolutely unprecedented outburst of economic activity which, by 1913, carried the volume of world-trade to $40,000,000,000, an increase in 13 years as great as the hitherto unprecedented growth of the preceding half century. Not even the war sufficed to stop the momentum of the movement, for, at the close of 1918, the volume of world-trade had reached $50,000,000,000, albeit this was measured in the inflated currency of the present day. Such are the figures; $50,000,000,000 in 1918 as against $2,000,000,000 in 1818. Is it any wonder that the continent that was the motivator, nucleus and chief beneficiary of this twenty-five fold increase in international trade should have been able to support a three-fold increase in population?

The agencies making all this possible were, of course, improved transportation and communication. A century ago such matters had not advanced radically since the Christian era. In 1818, there was not a single ocean-going steamship, not a mile of railroad, not a foot of telegraph wire or ocean cable. As for electric traction, motor trucks, airplanes, telephones and wireless telegraphy; these are all the product of our own generation. In 1914, the world's steam shipping aggregated fully 30,000,000 tons, while the world's railroads totalled 725,000 miles, more than three times the distance from the earth to the moon.

These revolutionary developments in world-trade brought certain inevitable consequences in their train, the most outstanding of which was the economic integration of the planet. However profound existing political cleavages, mankind was being rapidly welded into an economic whole. And, having been thus integrated, the entire world came under the influence of that primal law of modern economic life, the division of labor. The same fiat that apportions the labor of 1000 men to the making of a single machine, each man devoting himself to his minute but indispensable part, began sorting out the various regions of the earth, assigning to the different areas and their peoples those activities for which they were best fitted, and through specialization upon which they could best contribute to the maximum efficiency of world production and exchange. And in this process Europe was assigned a preeminently industrial role. Of course, this could not apply strictly to so vast and varied an area as an entire continent, many European regions, in fact, remaining predominantly rural. Nevertheless, taking Europe as a whole, we may say that the tendency was all away from agriculture and toward urbanization and industrial life. But since Europe had thus become the chief workshop of the world, the other quarters of the globe took on the correlative function of sending to Europe, in exchange for its finished products, foodstuffs to feed its workers and raw materials to feed its machines.—Lothrop Stoddard in *World's Work*.

SOCIETY LIBRARY

A SMALL library is maintained in the Members' Room at the Society offices in New York City. It is planned to keep on the shelves the principal engineering and technical books on automotive vehicle design and closely related subjects. This will provide the members with a compact library where they can make a concentrated study of automotive engineering problems. New and authentic automotive engineering volumes will be added to the collection from time to time and a complete file of Government and research organization bulletins covering subjects of interest to automotive engineers will be available for consultation.

A set of the German Technische Berichte has been courteously contributed by the National Advisory Committee for Aeronautics. These consist of separate technical memoranda issued, as confidential material during the course of the Great War, by the Aeronautical Supply Department of the German Air Force. The reports contain practically all of the official German aeronautical information recently compiled from the research conducted during this period, covering a wide range of subjects, such as propeller study, methods of calculating aircraft performance, analysis of engine tests, design of airplane engines and authentic wind-tunnel tests of approximately 350 wing sections. This material is of course all in the original German. Any member interested in a particular report can secure photostats of it and it is generally an easy matter to have translations made.

Suggestions from members as to books that are of great value to the automotive engineering fraternity will be welcome and receive due consideration. It is of course not intended to attempt to duplicate in any way the magnificent Engineering Societies Library that is housed in the same building in which the Society offices are located. The privileges of this splendid institution also are of course available to the members of the Society.

Current Standardization Work

A MEETING of the Iron and Steel Division was held in the rooms of the Old Colony Club at the Hotel Iroquois, Buffalo, on July 25. The principal work accomplished was the reviewing of the draft of the Steel Specifications and the Notes and Instructions referring to their chemical and physical properties and applications now printed on pages D1 to D44 inclusive of the S. A. E. HANDBOOK, this draft having been revised at the June 20 meeting of the Division. It is the purpose to make the specifications and notes and instructions a reliable guide to the best current metallurgical practice. The data will, like those of similar nature in the past, be of the greatest value to automotive engineers specifying the application of ferrous materials.

CAST-IRON VALVE-HEADS

At the meeting of the Iron and Steel Division members held on June 20 a report on the feasibility of adopting a specification for cast-iron valve-heads was submitted by C. N. Dawe. This report, given below substantially in full, recommending that the subject be tabled indefinitely, was approved by the Division.

Apparently a soft gray iron is in every way satisfactory for valve-heads, although the production of suitable castings is not a matter of chemical composition alone, but largely a matter of foundry practice. If a chemical composition were specified, the recommendation would have to specify also the time and the temperature of pouring, the number of heads to be cast at one time and whether they should be cast "in series or in parallel." All of these points affect the final product.

This is true of not only valve-heads but of any cast-iron part on a passenger car. There is, of course, the distinction between hard iron made partly of steel scrap and real soft gray iron, but the classification is too general to be called a specification.

In regard to the hardness of valve-heads it seems to be the consensus of opinion that this is the most important factor. A specification for it would be next to impossible to make at the present time owing to the variable conditions that exist in engine construction.

Before the hardness and analysis of valve-heads could be standardized, the hardness and analysis of cylinders would have to be established. It is believed that the cast-iron valve-head should be slightly softer than the cylinder iron on which the valve seats. The problem for each engine builder using this type of valve is to obtain a valve to suit his particular conditions with respect to cylinder hardness and chemical composition, which vary considerably today.

The reasons for recommending that the valve-head be slightly softer than the cylinder are many, but possibly the most important is that relating to service, as it is easier and less expensive to replace a valve than a cylinder. If the valve-head is harder than the cylinder, the seat in the cylinder will in time become "pounded out."

A chemical composition which, together with certain casting conditions, will produce a very soft and weak iron is to be avoided. Obviously a certain amount of strength is necessary, this meaning a proper percentage of combined carbon. Valve-heads should be made from an iron having a slightly less percentage of combined carbon than the cylinder with which it is to be used.

There are three general classes of cast-iron-head valve: (*a*) with heads electrically welded on, (*b*) with heads welded on by means of the acetylene torch and (*c*) with heads cast directly on the stem. Whichever process is used, annealing of the heads is necessary after welding, this operation affecting the resultant chemical composition with respect to the amount of combined carbon.

LOCK WASHERS

The S. A. E. Standard for Lock Washers, published on page C5 of the S. A. E. HANDBOOK, was adopted by the Society in 1911. It includes a light series and a heavy series for S. A. E. Standard bolts and machine screws. The standard has been criticised as not being comprehensive enough for general automotive work, especially for motorcycle practice against soft metal. This has been discussed at length by members of the Motorcycle Division in joint session with members of the Parts and Fittings Division and the Lock Washer Manufacturers Association. It has been decided that the standard should be revised, but limited to three sections of steel for a given bolt size. E. W. Hart was designated to formulate a recommendation for submission to the automotive industry. This is reproduced in the drawing and tables on the opposite page. It is requested that the members of the Society review the recommendation carefully as the subject is of direct interest to all connected with the design and construction of automotive vehicles or parts. Comments and criticisms should be sent to the office of the Society.

HEAD-LAMP ILLUMINATION

A joint meeting of the Illuminating Engineering Society's Committee on Automobile Vehicle Lighting and the Lighting Division of the Society's Standards Committee was held on June 29 in New York City to discuss the advisability of revising or extending the present recommendation for Head-Lamp Illumination so that vehicles equipped with gas headlamps can comply with it. The discussion indicated that final action will have to be based on laboratory and road tests and arrangements have been made for the running of such tests as are considered necessary.

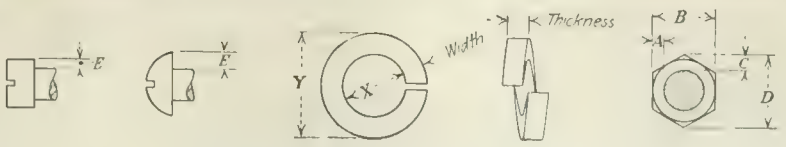
PAYROLLS IN EUROPE AND AMERICA

AN American company operating in Great Britain and France as well as the United States has prepared a comparison of rates of pay in those countries based on payroll rates prevalent in November, 1920. This shows a rate of 61.8 cents per hr. for the United States, 37.0 cents for France and 32.5 cents for Great Britain. It is stated that in considering these rates it must be borne in mind that the production per man per hour in France and Great Britain is not equal to that in America, and that the cost of production of similar articles in Great Britain and France is very little, if any, below the cost of production here.—*National Implement and Vehicle Association Journal.*

BLUEPRINTS

THE blueprints will never be discarded, and the point at which to choose between full-sized blueprints and reduced scale photoprints should be easily decided. Perhaps it would be well to make a tracing and work from blueprints for a time until it becomes apparent that no more changes will be made immediately and then photograph.

The only difference between a drawing for a full-sized tracing and one for the reduced photoprint aside from inking and cleaning is that the figures and notes should be made larger in proportion, but this does not detract in the least from the value of the average blueprint.—Harry Senior in *American Machinist.*



PROPOSED DIMENSIONS OF LOCK WASHERS.

Fillister Head Machine Screws

Screw Number	Diameter		Clearance[1]	E	X	Standard		Special Light		Special Heavy	
	Screw	Head				Section[2]	Y	Section[2]	Y	Section[2]	Y
2	0.086	0.132	0.003	0.023	0.089	1/32 × 0.022	0.1515	0.022 × 0.022	0.1330	1/32 × 1/32	0.1515
4	0.112	0.175	0.003	0.031	0.115	1/32 × 1/32	0.1775	1/32 × 0.022	0.1775	1/64 × 1/32	0.2087
6	0.138	0.217	0.005	0.040	0.143	3/64 × 1/32	0.2367	1/32 × 1/32	0.2055	3/64 × 3/64	0.2367
8	0.164	0.260	0.005	0.048	0.169	3/64 × 3/64	0.2627	3/64 × 1/32	0.2627	1/16 × 3/64	0.2940
10	0.190	0.303	0.010	0.056	0.200	1/16 × 3/64	0.3250	1/64 × 3/64	0.2937	1/16 × 1/16	0.3250
12	0.216	0.345	0.010	0.065	0.226	1/16 × 1/16	0.3510	1/16 × 1/64	0.3510	5/64 × 1/16	0.3822

Round Head Machine Screws

2	0.086	0.154	0.003	0.034	0.089	1/32 × 1/32	0.1515	1/32 × 0.022	0.1515	3/64 × 1/32	0.1827
4	0.112	0.202	0.003	0.045	0.115	1/16 × 1/32	0.2400	3/64 × 1/32	0.2087	5/64 × 1/32	0.2712
6	0.138	0.250	0.005	0.056	0.143	5/64 × 1/32	0.2992	1/16 × 1/32	0.2680	5/64 × 3/64	0.2992
8	0.164	0.298	0.005	0.067	0.169	5/64 × 3/64	0.3252	5/64 × 1/32	0.3252	3/32 × 3/64	0.3565
10	0.190	0.346	0.010	0.078	0.200	3/32 × 3/64	0.3875	5/64 × 3/64	0.3562	3/32 × 1/16	0.3875
12	0.216	0.394	0.010	0.089	0.226	3/32 × 1/16	0.4135	3/32 × 3/64	0.4135	1/8 × 3/64	0.4760

S. A. E. Standard Bolts

Bolt Diameter	Clearance[1]	A	B	C	D	X	Standard		Special Light		Special Heavy	
							Section[2]	Y	Section[2]	Y	Section[2]	Y
3/16 No. 10	1/64	...	..	...	.	13/64	5/64 × 3/64	23/64	1/16 × 3/64	21/64	5/64 × 1/16	23/64
1/4	1/32	3/32	3/8	0.128	0.505	9/32	3/32 × 1/16	15/32	3/32 × 3/64	15/32	3/32 × 5/64	15/32
5/16	1/32	3/32	1/2	0.133	0.578	11/32	1/8 × 1/16	19/32	1/8 × 3/64	19/32	1/8 × 3/32	19/32
3/8	1/32	3/32	9/16	0.137	0.650	13/32	1/8 × 3/32	21/32	1/8 × 1/16	21/32	1/8 × 1/8	21/32
7/16	1/32	3/32	5/8	0.173	0.722	15/32	5/32 × 1/8	25/32	5/32 × 1/16	25/32	5/32 × 5/32	25/32
1/2	1/32	1/8	3/4	0.183	0.866	17/32	11/64 × 1/8	7/8	11/64 × 1/16	7/8	11/64 × 11/64	7/8
9/16	1/32	5/32	7/8	0.224	1.011	19/32	3/16 × 3/32	31/32	3/16 × 3/32	31/32	3/16 × 3/16	31/32
5/8	1/32	5/32	15/16	0.229	1.083	21/32	13/64 × 5/32	1 1/16	13/64 × 3/32	1 1/16	13/64 × 13/64	1 1/16
11/16	1/32	5/32	1	0.234	1.156	23/32	7/32 × 3/16	1 5/32	7/32 × 1/8	1 5/32	7/32 × 7/32	1 5/32
3/4	1/16	5/32	1 1/16	0.239	1.228	13/16	1/4 × 3/16	1 5/16	1/4 × 1/8	1 5/16	1/4 × 1/4	1 5/16
7/8	1/16	3/16	1 1/4	0.284	1.444	15/16	17/64 × 1/16	1 15/32	17/64 × 5/32	1 15/32	17/64 × 17/64	1 15/32
1	1/16	7/32	1 7/16	0.330	1.660	1 1/16	5/16 × 1/4	1 11/16	5/16 × 3/16	1 11/16	5/16 × 5/16	1 11/16
1 1/8	1/16	1 1/4	1 5/8	0.376	1.877	1 3/16	3/8 × 1/4	1 15/16	3/8 × 3/16	1 15/16	3/8 × 3/8	1 15/16
1 1/4	1/16	9/32	1 13/16	0.422	2.093	1 5/16	7/16 × 1/4	2 3/16	7/16 × 3/16	2 3/16	7/16 × 5/16	2 3/16
1 3/8	1/16	5/16	2	0.468	2.310	1 7/16	7/16 × 5/16	2 5/16	7/16 × 1/4	2 5/16	7/16 × 3/8	2 5/16
1 1/2	1/16	11/32	2 3/16	0.513	2.527	1 9/16	1/2 × 5/16	2 9/16	1/2 × 1/4	2 9/16	1/2 × 3/8	2 9/16

All dimensions in inches.
[1]Inside diameter of washer less diameter of bolt or screw.
[2]The width of the washer is always given first; as 1/4 x 1/8, 1/4 being the width and 1/8 the thickness.

SCREW-THREAD STANDARDIZATION

CONCURRENTLY with the recent issuance of the progress report of the National Screw Thread Commission, the American Engineering Standards Committee sectional committee on Standardization and Unification of Screw Threads, for which the Society and the American Society of Mechanical Engineers are sponsors, began to function. The Sectional Committee was organized primarily to consider the Report of the Commission and the adaptability of the recommendations thereof to practice, and to provide a suitable body for eventually negotiating international screw-thread standards, especially with Great Britain. Similar work in England is conducted by the British Engineering Standards Association, which is much the same as the American Engineering Standards Committee in scope and purpose. C. le Maistre, secretary of the British Engineering Standards Association, at the time of his visit to America in 1919, showed considerable interest in the progress being made in this country toward more complete screw-thread standards, their correlation with foreign standards, particularly the British, and their general adoption in America. This was about the time that the American Engineering Standards Committee began to take definite form and Mr. Le Maistre stated that as the British Engineering Standards Association was anxious to confer with American representatives on this work, an organization such as the American Engineering Stadards Committee was recognized as the logical one within which all American interests could be represented and through which international consideration of this subject could be best negotiated. It was therefore largely by reason of the request of the British Engineering Standards Association that the Sectional Committee was organized.

The report of the National Screw Thread Commission was at that time in process of development, public hearings being held at various industrial centers. In September, 1919, a special committee of the Society[1] was appointed by President Manly to review the tentative report of the National Screw Thread Commission and suggest any changes that seemed desirable for automotive practice.

The first meeting of the Sectional Committee was held in New York City, June 9, 1921. Luther D. Burlingame and Ralph E. Flanders were elected chairman and vice-chairman respectively with C. B. LePage as secretary. It was recommended that George E. Hammann and E. H. Reed be elected members of the committee to represent the machine-screw manufacturers. It is the intention to secure an additional member qualified to represent the structural-steel interests. The members of the Sectional Committee are:

Representing the American Society of Mechanical Engineers

A. R. Baylis
Elwood Burdsall
L. D. Burlingame, *Chairman*
G. S. Case
S. G. Flagg
R. E. Flanders, *Vice-Chairman*
E. M. Herr
A. M. Houser
A. H. Moore
W. R. Porter
F. O. Wells

Representing the Bureau of Standards

H. W. Bearce

Representing the Society of Automotive Engineers

P. W. Abbott
D. G. Baker
Earle Buckingham
E. H. Ehrman
H. E. Fromme
W. F. Graham
H. L. Horning
C. M. Manly
E. O. Spillman
O. B. Zimmerman

A brief review was given the committee of the action taken at a general meeting of machine-screw manufacturers in New York City, May 18, which favored the adoption in machine-screw practice of the National Screw Thread Commission's recommendations for the coarse-series medium-fit and the fine-series medium fit screw-threads.

A communication from the Canadian Engineering Standards Association was read to the effect that if the proposed cooperation with the British Engineering Standards Association should lead to an international conference on screw-thread standardization, it would like to participate. The Sectional Committee indicated that if such a conference were called, the Canadian Engineering Standards Association would be invited to send one or more official representatives.

Proposals were offered for consideration by the Sectional Committee embodying the following named subjects in connection with study of the National Screw Thread Commission's report:

(1) Magnitude of tolerances
(2) Distribution of neutral zone
(3) Gaging system
(4) Desirability of a large number of variations and classification of screw-thread fits
(5) Errors in lead
(6) Series of thread pitches

The general opinion of the committee was that exact information from manufacturers who have adopted the National Screw Thread Commission tolerances should be available for review by the committee. There was divided opinion as to whether the distribution of the neutral zone should be considered by the committee, but the neutral zone was thought to be impracticable in connection with some grades of screw thread, especially when it extends below basic on the screw. It was felt that the inclusion of a description of a gaging system in the National Screw Thread Commission's Report is advantageous as indicating an acceptable practical method. The system set forth in the report is offered by way of suggestion and not a definite recommendation. There was some discussion as to the desirability of reducing the classes of thread fit from eight to six by eliminating the "loose fit" on the fine threads and the "close fit" on the coarse threads.

The subject of errors in lead was not discussed at great length but the opinion was expressed by some that maintaining accuracy in lead is more important than maintaining accuracy in pitch diameter. A suggestion was made that an intermediate third series of thread pitches be adopted and that each series be made in one class of fit only.

After discussion of ways and means of studying the Commission's report, and presenting it to those interested in connection with the Sectional Committee's activity, it was thought that a condensed version of the report should be issued. A subcommittee has been appointed by Chairman Burlingame to consider this matter, as well as the five subjects brought up at the meeting as enumerated above. Those designated for this purpose are Charles M. Manly, chairman, P. W. Abbott, Earl Buckingham, G. S. Case, R. E. Flanders, G. E. Hammann and W. R. Porter.

An abstract of the progress report of the National Screw Thread Commission was published in the October, 1920, issue of THE JOURNAL. The complete report, consisting of 108 pages, is now available in printed form, having been issued by the Bureau of Standards, Washington.

[1] See THE JOURNAL, October, 1919, p. 280.

TRACTORS IN FRANCE

THE French Ministry of Agriculture has compiled statistics which show the growth in the use of farm tractors and other agricultural machines in France. In 1913 there were only 295 farm tractors in use and practically all of them were American machines. In 1920 the number had increased to 5400, most of them being of French manufacture. Three large companies have developed their production of agricultural machinery so that they are setting aside a percentage for export.—*National Implement and Vehicle Association Journal.*

The Mutual Adaptation of the Motor Truck and the Highway

By A. T. Goldbeck[1]

Semi-Annual Meeting Paper

FRANKLY, the aim of this paper is to stimulate thought on an idea that is not new, but to which little attention has thus far been given. My excuse for asking you to consider and think hard about it is my earnest desire, and it must also be your desire, to see accomplished the greatest possible economy in transportation over our highways. Here is the fundamental proposition. Expense of highway transportation involves a large number of items, which may be grouped into those directly concerned with motor-truck operation and those involving the highway, and our aim should be to devise our highways and our motor vehicles and adapt them one to the other so that the greatest economy of transportation will result.

The ultimate cost of highway transportation is borne by the public, who are very much interested in seeing this cost reduced to a minimum. It is of very little concern to the ultimate consumer how it has been possible to reduce his transportation bill. He cares little whether this economy has been effected for him by vastly increasing the economy of actual operation of the motor vehicle, or the saving has been brought about through reduced cost of construction and maintenance of his roads. He sees the final result, low cost of freight transportation by motor vehicle, and is satisfied that here is a sound reliable and lasting utility which it will pay him to encourage, patronize and support.

Destruction of Road Surfaces

There is no need of dwelling on the enormous destruction of our road surfaces in the past several years. We all know that something is radically wrong when a road disappears in a single season and sometimes overnight. We do not have to ponder to arrive at the conclusion that when such conditions obtain there must surely be tremendous waste in that kind of highway transportation. The blame need not be laid on any one in particular, for stress of circumstances was responsible for imposing on our roads an unpredicted and unprecedented volume and weight of traffic.

Certainly no one desires to see our highways, constructed today, destroyed in the next 2 or 3 years, for their reconstruction is a long and tedious operation and increases very materially the cost of our highway transportation bill. I take it that we all wish our roads to have a life compatible with ultimate economy in their use. We would like to see types of roads constructed that will carry their traffic with the least possible combined road and vehicle cost. Surely that is an ideal to be sought after, and it goes without saying that both highway and automotive engineers must be supplied with very definite facts before they can design their particular parts of such an ideal motor transportation system, in which the motor vehicle and the highway are so mutually adapted to each other that the most efficient transportation will result. Right now these facts do not exist. In their place we have legislation that limits the maximum loads to be carried on the highways and the speed with which the motor vehicles are to run, and imposes license fees that are not based on scientific fact. Legislation has been necessary to prevent the too rapid destruction of the highways and of necessity has been arbitrary legislation which possibly may not result in giving the public the greatest return for the money expended. Thus, the maximum weight of truck is limited to a certain figure because weights above this amount have caused rapid destruction of the roads. Yet certain types of hauling can undoubtedly be done with heavy units of traffic, and were the figures and facts available it might be found that where this kind of hauling is necessary much economy would result in rebuilding the highway so that it will carry the heavy units of traffic. Again, it may be that although the particular kind of hauling can be done most cheaply with heavy units of traffic, so far as actual motor-truck operation is concerned, it may nevertheless pay to increase the motor-truck operation cost somewhat by using lighter units and thus effect a saving in the items of road expense.

Unfortunately, facts are not available, and the automotive engineer and the road engineer should get together and gather information that will give them a more definite basis upon which to decide on the design of the truck and the design of the road. At present each is deciding for himself on his own particular problem with too little consideration of the aim to be accomplished, ultimate economy in highway transportation.

Designing the Truck to Conserve the Road

I wonder how much thought has been given on the part of the automotive engineer to the problem of motor-truck design with the idea of road conservation. It would seem that much might be accomplished by the motor-truck designer toward attaining an ideal transportation system if he would give considerable thought as to what effect his latest creation will have on the road. I am wondering whether the automotive engineer could not with advantage follow in the footsteps of his brother designer of the locomotive. When it was found economical to increase the weight of trains and the weight of the locomotive from the standpoint of operation of the train, it was likewise found economical to distribute the weight of the locomotive on more wheels so that the destruction of the roadbed and the track might be kept within reasonable limits.

Unquestionably, the bulk of our serious road destruction results from heavy wheel concentrations, granting, of course, defective design of drainage, subgrade and road surface as attendant contributory causes. This being the case, would it not seem desirable for the motor-truck designer to look into the question of distributing the weight on his heavy trucks to more than four wheels or even more than six? Except so far as bridges are

[1]Engineer of tests, Bureau of Public Roads, Washington.

concerned, I can see no reason for limitations on the gross load of the motor truck provided it is distributed over the road surface so that the wheel concentrations are kept within reasonable bounds. I realize that there must be tremendous mechanical difficulties to be overcome in such a design but if it pays, always keeping in mind the ultimate cost of haul, surely they can be overcome. In working out the possibilities of designs, is it not evident that the highway engineer and the automotive engineer must get together and pool their ideas? How big the wheel concentrations should be and what the minimum desirable spacing is, are problems for the highway engineer; the mechanical troubles will be solved by the motor-truck designer.

As a result of several years of research made with the idea in view of more rational design of highways, the Bureau of Public Roads has developed facts which lead us to believe that real conservation of our roads could surely be attained if it were practicable and economical from the motor-vehicle standpoint to apply these facts to the design of the motor truck. In a previous paper before the Society[2] attention has already been called to the manner in which heavy wheel concentrations are distributed through the road surface to the underlying subgrade. It has also been pointed out that by actual field and laboratory tests of the Bureau of Public Roads we have shown that these wheel pressures created pressure intensities on the subgrade that may greatly exceed the bearing value of the subgrade at various times in the year. Of course, when such a condition obtains it is not long before the road surface is so badly distorted that it breaks up under traffic, and the remedy is more expensive road construction because of the necessity for increased thickness of surface, better drainage or expensive subgrade treatment. Had the wheel concentrations been smaller, in very many cases the pressure carried to the subgrade would not have exceeded the subgrade support. The surface would not have been badly distorted and the road would have served the traffic for years. It must be perfectly plain in cases of this kind that by reducing wheel concentrations we effect real economy through the conservation of the road. Reduction of wheel concentration does not mean reduction in the total load carried by the truck; it may mean an increased load. But it does mean either a more equal distribution of the load on the wheels or it may mean the use of more wheels.

As some of you have no doubt been following our impact studies, you have noted the vast difference in the impact pressure produced on the road surface by a moving truck, depending upon its tire equipment.[3] You have observed how greatly the impact effect on the road is reduced, depending upon the cushioning properties of the tire. You have seen how tremendous the impact can be when the solid tire wears down to an inch in thickness. You have also noted the better cushioning qualities of tires having high static deformation and, finally, you no doubt noticed the extremely small impact produced when the truck was equipped with pneumatic tires. These facts are very significant. From the road engineer's standpoint they indicate the possibilities, at least, of road conservation through the use of proper tire equipment, and tremendous possibilities in road conservation were it entirely practicable to use tires having the highest cushioning properties. No doubt there are other items of truck design affecting its destructiveness to the road surface, but it is not my wish to go into a detailed discussion of this phase of the problem at this time. I simply mention these few points to bring to the attention of the automotive engineers the possibilities of their great assistance in bringing about decreased cost in highway transportation through the design of the motor vehicle in such a way that it will conserve the road surface without necessarily decreasing the actual motor-truck economy. The possibilities are apparent. Why not definitely establish the facts and apply them to advantage?

[2] See THE JOURNAL, April, 1921, p. 339.
[3] See *Public Roads*, March, 1921.

Society Cooperation with Highway Officials

We must arrive at these facts through cooperative effort and what I would like to see accomplished is the formation of a joint committee by the Society and a highway engineering organization such, for instance, as the Association of State Highway Officials. I would like to see this committee study the highway transportation problem with the ultimate idea of decreasing the cost to the public of highway transportation. This will involve studies that will show what types of road construction and what types of vehicle are best suited to one another, for particular stretches of road carrying definite commodities. Such a cooperative committee could make a thorough study of the effect of the motor truck on the road and, working in close harmony, could determine whether it is practicable or desirable to suggest changes in the design of either the motor truck or the road to make them more adaptable to one another.

The highway transportation problem must be considered in its entirety in just the same way that the problem of railroad transportation is considered. The time has certainly arrived when the motor-vehicle department and the road department of our highway transportation system should work in close harmony. They should understand each other's difficulties and work with that spirit of cooperation which will lead to the most efficient results. A committee such as I advocate will do much to bring about this cooperation and there is no doubt that through its studies facts will be established which will reduce greatly our highway transportation costs.

Commercial Aviation in the Eastern Hemisphere

By Edward P. Warner[1]

Annual Meeting Paper *Illustrated with* Photographs and Drawings

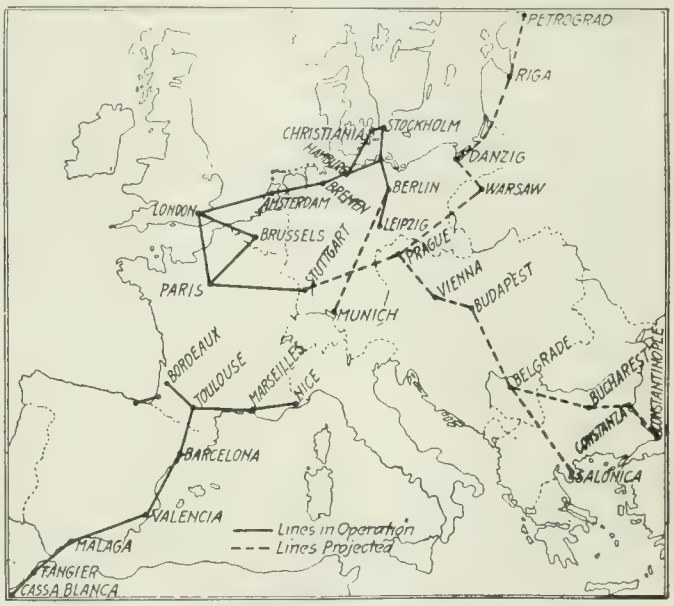
COMMERCIAL aviation in Europe as in America may be said to have sprung full-fledged into being shortly after the signing of the Armistice. Although attempts had been made at commercial flying before 1914, a few wealthy men having used airplanes for hasty trips from one city to another and some abortive attempts having been made at mail carrying as a "stunt," the flying done had no real significance except as propaganda for the airplane in general and had little more significance in that respect than had the exhibitions which were a common feature of State and County fairs and other fêtes in this country. One exception must be made to this statement. The Hamburg-American line had been running, with the Schwaben and other Zeppelin airships, lines between some of the large cities in Germany, as well as making excursion tours over Berlin, and had been meeting with some success, although the public support probably was not large enough to make the operation of this line a paying venture aside from its value in developing the airships and in giving data on their operation which were subsequently put to military use.

The enormous development of aircraft under the stress of war not only increased the reliability of airplanes and airships and made it more practicable and safer to employ them in commercial flying, but it also awakened the public to the fact that flying is a reality, that it is a mode of locomotion possible for everyone and not merely for a few supermen, trick bicycle riders and acrobats; and it furthermore involved the creation of a large supply of aircraft which inevitably stood idle after the signing of the Armistice and invited every effort to find for them some new non-military use. Commercial flying, despite these incentives for its commencement, was a little slow in starting after the coming of peace, as all European governments hesitated to throw open the air in their territory to indiscriminate navigation before they had had a chance to make a thorough study of the conditions to be imposed on such navigation and of the control which would have to be exercised in the interests of the safety of the State and the safety of its nationals.

Civil flying in England was officially opened under authorization of the Air Ministry, May 1, 1919. Although a little passenger-carrying had been done over the Easter week-end, 10 days before that date, it had been strictly limited to service types of machine and to ex-service pilots and to flights extending not more than three miles from the home field. On May 1, however, the Air Ministry issued its regulations for the operation of civil aircraft, and those regulations are substantially the ones under which flying is carried on to-day, as they were nearly identical in most respects with the terms of the International Air Convention adopted by the Peace Conference of Versailles.

[1] Jun. M S A E.—Secretary, sub-committee on aerodynamics, National Advisory Committee for Aeronautics, Langley Field, Va.

For the first few months after the official opening of civil flying in the British Isles, the work was confined to passenger-carrying by special request and to attempts on a small scale at the carrying of mails within the British Isles. This mail carrying, like all that which has since been done in the major European countries, was done by operating companies receiving a fixed fee from the Government. No European power operates its own mail planes, as has been the practice here.



Projected and Regularly Operating Air Routes in Europe at the Beginning of 1921

International flying between England and the Continent began Aug. 26, 1919, the International Air Convention having then been drawn up and ratified by the principal states. A line between London and Paris was started at once to carry passengers, express and mail, but the mail carrying was of negligible importance for a considerable time, as the rates charged for postage were almost absurdly high; the letter postage being 2 shillings at first. The postage and the express services were well patronized from the beginning and the first line was soon joined by several others, so that there are now five distinct services in operation between the London and Paris terminal airdromes. In addition to these services there are now functioning regular lines between London and Brussels, London and Amsterdam, Paris and Brussels, Bordeaux and Nice, Amsterdam, Hamburg, Copenhagen, and Berlin, Toulouse and Casablanca via Tangier, and on a few other less important routes. This does not include a number of services which are advertised as regular but do not, as a matter of fact, run except on particular occasions when passengers offer themselves. In Germany, for example, there are fixed fares

over about 100 routes within the German Republic, but no regular journeys on fixed schedules except in one or two instances or except on such special occasions as the Leipzig Commercial Fair when numbers of passengers were carried from Berlin by airplane. Much more ambitious projects also are under consideration, one in particular being planned to connect Paris with Central and Eastern Europe, the fundamental line being from Paris to Prague with extensions leading to Warsaw, Nish, Salonica, Budapest, Constantinople, Bucharest and Constanza. The lines in operation and projected are shown in Fig. 1. Some routes of course offer much more favorable opportunities than others for aerial transport. The chief requirements for a good airplane route are that the traffic shall be large and wealthy, that the terrain shall not be excessively wild or mountainous, and that surface travel shall be slow and uncomfortable. All of these requirements are satisfied in the highest degree by the London-Paris and London-Brussels routes, the Channel crossing in a small steamer in bad weather, with two trans-shipments of hand baggage, being an atrocity of the first order. Again Great Britain finds the Channel of assistance in building up the potential means of national defense, this time in a most unexpected and indirect way.

The international services were not well patronized during the winter, but the traffic increased steadily during the past summer. During the month of July, 933 passengers traveled from London to Paris by air, 10,554 letters were carried between England and the Continent and goods to the value of £100,750 were imported into and exported from Great Britain by air in August. The number of commercial aircraft crossing the Channel increased from 140 in September, 1919, to 486 in August, 1920, and the average size of the airplanes in use also increased constantly.

No airship services are running at present, but they are likely to be started soon both in England and in Germany. The Air Ministry has offered to furnish rigid airships to operating companies, and some long-distance service would probably have been started before now had it not been for the great economic tension throughout the world. In Germany, the Zeppelin company started immediately after the Armistice to operate a service between Berlin and Friedrichshafen with the Bodensee, a ship of only 700,000 cu. ft. but far more efficient than anything previously built. The Bodensee has since been enlarged, and the Zeppelin officials declare themselves anxious to re-start the service with the Bodensee and her sister ship the Nordstern as soon as they can secure guarantees from the Allies that these ships will not be confiscated under the terms of the treaty of Versailles as soon as they are put in commission. The airship is the ideal vehicle for long routes with moderately heavy traffic, and there should be an excellent opening for trans-Atlantic lines and for lines from England to India and to South Africa. The civil service in India would be considerably more attractive if Calcutta were only three and one-half days from London and two weeks could be spent at home out of a three weeks' annual leave. The airship has little chance in commercial work, however, as long as the present difficulties with landing and housing persist, and it will be a success when, and only when, the mooring mast is perfected to a point where a large rigid airship can be moored out continuously and in all weathers.

The first necessity of passenger carrying by air is public confidence in the reliability and safety of the service. People are willing to send their letters where they will not trust themselves, and commercial passenger-carrying by air can never really succeed unless it has public opinion and a supporting press behind it. The British undertakings have been very fortunate in this respect from the first, and the commonplace manner in which travel by air is now accepted by the general public is amazing to a foreign visitor. On entering a tourist agency in London at the present time and asking for a ticket to Paris, one is regularly met by the matter-of-fact query, "rail or air?", and the same question is put when express packages are brought in for shipment to the Continent. There is one agency in London which handles air traffic almost exclusively, its other business being purely side-lines, the adjective "aerial" appearing in the very name of the corporation, and this agency has established itself on the ground floor on a corner in Piccadilly Circus, one of the busiest spots in London. The condition is somewhat comparable to that which would exist if an American airplane ticket-agency took space 30 x 45 ft. on the ground floor at the corner of Fifth Avenue and 42nd Street in New York City. In Germany the booking of air passages forms an important part of the business of the Hamburg-American agency in the Unter den Linden. That public confidence exists in so large a degree is largely due to the favorable attitude of the press which, instead of seizing every opportunity to present accounts of accidents under glaring headlines and to magnify their significance, has been uniformly friendly and has sought rather to emphasize the news favorable to aviation both in the news columns and editorially. The friendly attitude of what is probably the largest of all newspaper syndicates is traditional, Lord Northcliffe's personal interest in aviation having extended far back into the pioneer days and been expressed in concrete form by the offer of large prizes for the trans-Atlantic flight and other aerial feats.

No matter how friendly the newspapers may be, however, they can do no more in the long run than to make a fair presentation of the facts and it is impossible for commercial aviation to flourish unless the safety of flight is fairly comparable with that of other means of transport. In order that reliable data on this point may be at hand, the British Air Ministry has compiled statistics relating to accidents in commercial flying, both to furnish for designers information on the causes of such accidents and the best means of preventing their recurrence and to permit the public to judge fairly of the risk which they run in traveling by air. These statistics show that during the first eleven months of commercial flying in England and between England and the Continent there was a total of 24 accidents, four of which resulted in the death of one or more occupants of the airplane. The pilot was killed in all four cases, while in the whole 11 months one pasenger was killed. The average death rate among pilots was 0.415 per 1000 hr. or one death for every 2410 hr. of flying, while the average among passengers was 0.015 fatalities per 1000 passengers carried and 0.055 per 1000 passenger hr. This works out roughly at one death for every 67,000 passengers and every 18,200 passenger hr. or, taking the average cruising speed of commercial aircraft as 90 m.p.h., as one fatality for 1,640,000 passenger-miles. During the year 1917 the passenger death-rate for railroad travel in the United States was one for every 3,220,000 passengers carried, a danger ratio of 48 to 1. In some years American railroads have shown themselves less than 20 times as safe as has the airplane in this, its first,

FRONT AND REAR VIEWS OF THE WESTLAND LIMOUSINE AIRPLANE, WITH THE ENTRANCE TO THE CABIN IN THE SMALL CENTRAL ILLUSTRATION

year of commercial use. If the calculation includes all injuries as well as deaths, the relative showing of the airplane is considerably more favorable. The airplane death-rate is certainly very much less than the uninitiated would generally suspect, but it is still much too high and must and can be further reduced by research, by improvement in design, and by more complete and systematic ground organization, all of these call for Government aid.

Second only to safety in importance, and even ahead of it insofar as the carriage of mails and express is concerned, is economy. The cost of air services is still rather uncertain, as the lines have not been in operation long enough to give very many data on depreciation and running costs. The most exhaustive study to date is that made by H. White-Smith in a paper presented to the Air Conference held in London last September. Mr. White-Smith analyzed the costs of operating a service with several types of airplane and seaplane, including some new machines of commercial types and some converted service airplanes, and showed that the most economical machines, the largest ones in most cases, could operate profitably carrying passengers between Paris and London for £5, 10s. ($19.50 at the present exchange), if the machines could carry a full load on every trip. Mr. White-Smith's figures were based on a life of 3000 flying hr. for the airplane and 2000 flying hr. for an engine and included insurance against crashes at a rate of 15 per cent. The Canadian Air Board recently issued a memorandum on depreciation in which the conclusion was drawn that the life of an airplane under ordinary use is 700 flying hr. and that the crash risk is 0.2 per cent every flying hour, so it is evident that there is still wide difference of opinion among the authorities on the basis to be adopted in calculating costs. In durability, as in safety, there is room for decided improvement, and there is no doubt that flying life will be much increased in the near future.

The actual costs have shown a tendency to steady reduction. The fare charge on the London-Paris route was originally 20 guineas but has since been decreased several times and now stands at 10 guineas ($37.00) for the one-way journey and 18 guineas for the round-trip. The fare to Brussels is the same, while that to Amsterdam is 15 guineas one way. The rate between London and Paris by boat and rail via Dover and Calais is £3, 15s., 8d., so that the excess of airplane fare over that for service transportation is 178 per cent. Frank Searle, manager of the Aircraft Transport & Travel Co., who was largely responsible for the reduction in rate, lays great emphasis on the necessity of reducing the fare still further to increase the use of aerial transport to a point where machines can be run in considerable numbers, thus decreasing the percentage of overhead to be charged to each trip and also in order that they can run regularly with a full load. Mr. Searle prophesied, in an interview in the London *Times*, the reduction of the London-Paris fare to seven pounds in the relatively near future. The fares on other services are of the same order except in Germany, where the extreme depreciation of the currency makes all costs ridiculously low when referred to American money. The fare between Berlin and Leipzig during the Leipzig fair, for example, was only 800 marks, the equivalent of about $15 as the exchange then stood.

The charge in England for an "aerial taxi" for two people is 2s. 6d. (44 cents) per mile, and an airplane can usually be had to start for anywhere on an hour's notice. This fare is only 2½ times as large as that for an earth-bound taxi in London, and it costs approximately the same amount to travel by airplane in England and by taxi in New York.

INSURANCE

An essential to any business is insurance, and that is now being handled by a number of firms. Particularly interesting is the invasion of the field by Lloyds' who have recently retained consulting aeronautical engineers with a view to registering aircraft and rating them as risks, just as they have done with ships for many years. It appears that the aerial, like the marine, underwriters will be far harder on the man responsible for an accident than will the State, and it has already been suggested that a crash in landing is absolutely inexcusable and that a pilot who once damages an airplane in landing on a good field should be made forever uninsurable.

Insurance rates at the present time are about 30 per cent per annum for passenger aircraft traveling over good country, with a reduction of 0.2 per cent on the face value of the policy for every hour of flying after the first 100 hr. Airplanes used for stunting cannot be insured ordinarily.

There are practically no data on which to base an estimate of the cost of an airship service, but Air Commo-

FOUR VIEWS OF THE VICKERS VIMY COMMERCIAL AIRPLANE EQUIPPED WITH A ROLLS-ROYCE EAGLE ENGINE

dore E. M. Maitland has estimated that with ships similar to the R-34 a 15 per cent profit could be made carrying passengers from England to Egypt for £50, to India for £100, and to Australia for £190. These figures are from 10 to 70 per cent in excess of the first-class steamer fares, and the saving of time would be from 60 to 70 per cent.

Government Assistance

There is no European nation which has not clearly seen that the airplane can be kept in readiness for use in war only through the development of its use in commerce and that it is a clear function of Government to assist their use in commerce by every means in its power. The development of an air traffic under the control of its nationals is felt to be more important to many States than is the development of a similarly controlled merchant marine. In addition to the direct military usefulness of the airplanes developed for commercial work there is an additional motive in the value of air transport as a link between the home country or the dominions or colonies, and an analysis of the measures taken by the various Governments shows that this last incentive is always in mind and it has been the guiding star of such enterprise as the Government-encouraged, although not actually Government-assisted, flights from England to South Africa and from England to Australia in the development of the "Imperial Air Routes" of which more will be said later, and in the efforts of the French and Belgian Governments to steer air commerce in the direction of their respective colonies in West Africa. Every improvement makes it easier for the dominions and binds them more closely to the parent country.

If the necessity of Government assistance of some sort in giving commercial flying its start is conceded, there are four forms which it may take. It may be extended through direct purchases of airplanes for the military establishment or for other branches of Government, as is the case here. Secondly, it may take the form of a direct subsidy of the industry, of the payment of part of the costs of recognized airplane forms by the Government, thus making it possible to reduce the cost of operation of transport lines. A modification of this scheme, and one more commonly adopted, is the granting of monetary assistance by the Government to operating companies, instead of to manufacturers, on a basis of services actually operated and proportionate to the extent of the service. This is the system on which the French Government has chiefly proceeded and it is also to be adopted by the Polish Government to encourage the opening of the service between Prague and Warsaw. Finally, instead of granting any direct assistance to firms engaged in the manufacture or operation of aircraft, the Government may offer indirect assistance by furnishing the ground organization for the services and by encouraging research aiming to obtain fundamental data for the production of more useful and more economical aircraft. It is to this last method that the British Government has chiefly adhered up to the present time. At the time of the opening of commercial aviation, Winston Churchill, then Secretary of State for Air, voiced the opinion that commercial aviation must fly alone, and despite occasional protests and appeals for help the British Government has adhered throughout to that policy. The assistance granted in Great Britain has included the provision and upkeep of state airdromes open to both commercial aircraft and those owned by private individuals. Hangars can be rented at these fields and supplies and repairs of all sorts can be secured. At present, there have been listed over 300 fields in the British Isles which are available for use by civilian pilots; this does not include emergency landing places, but only regular fields kept in proper condition for the reception of aircraft. If flying fields were distributed with the same intensity over here there would be 130 in New York State alone. The number now available, however, is felt to be insufficient for convenience and safety, and it has been proposed recently that the major air routes be marked by a continuous strip of cleared ground about 100 yd. wide, permitting of a forced landing at any point along the route. This strip would be lighted continuously for night flying and a charged cable would possibly be laid along the route to permit of electric direction-finding in a manner similar to that employed in recent experiments with shipping in New York harbor. No official steps looking toward such elaboration of the air routes have been taken as yet, however. The most notable achievement of the Air Ministry in long-distance route-marking was the laying out of a line of landing fields from Cairo to Cape Town, and another string partially covering the road to Australia. Great central airdromes for travel to the dominions have been established at Karachi and at Heliopolis, near Cairo. The courses followed in the path-finding flights which marked out the Imperial air routes, made by Sir Ross Smith and Captains Broome and Cockerell and Captain Ryneveld, are shown in Fig. 2, together with the trans-Atlantic courses of Sir John Alcock and of the NC-4. Furthermore, the State maintains an elaborate meteorological service preparing a special weather map for aviators daily and sending out weather bulletins by radio at frequent intervals throughout the day, and it has erected two aerial light-houses at Croydon and Lympne, the latter of which points lies virtually on the London-Paris route. Concerning the terminal customs airdrome at Croydon, I shall have something more to say later.

Night flying on regular services has not yet been undertaken because of the danger involved. If commercial flying is to exercise any large influence on travel except on a few selected routes of a very special character, it is absolutely essential that journeys be made at night, and this calls for decided modification in the types of aircraft employed. The London-Paris route, as already remarked, is a special case where night flying is not required, as the changes of vehicles required and the crossing of the international boundary make a night journey by the ordinary means of travel rather unpleasant, but that route has little bearing on our problems here, and a daytime airplane line between Boston and Washington, for example, could never hope for any very large patronage as long as the Federal Express makes it possible to make the journey without losing 1 min. of the business day. Night-flying airplanes must be multi-engined so as to be absolutely insured against sudden forced landings, they must be specially fitted for the convenience of the passengers, and they must have a reasonably low landing-speed. In general, the high speed need not exceed 90 m.p.h. Furthermore, night flying is absolutely dependent on the provision by either the Government or private enterprise of an elaborate ground organization, including numerous well lighted landing-fields and many aerial lighthouses or searchlight stations. In these respects the marine aircraft traveling between seaports and keeping over the water has a decided advantage over land types, as it can depend on marine

ighthouses already established for finding the way and s it is nearly always possible to make a safe landing on he sea with the aid of a few parachute flares and lights n the seaplane, even on a moonless night.

The British Government, in addition to providing round organization, has continued its research activiies and distributed broadcast the results of the work lone at the Royal Aircraft Establishment and at the National Physical Laboratory, much of which is now lanned to have a special bearing on commercial aeroautics, and it has during the past summer held a very uccessful competition for commercial aircraft of three ypes, large land machines, small land machines and amhibians. British experience points a few lessons which ay be of great value to us at present. In the first lace, it has always been found that commercial and ilitary aviation must be considered separately and that he necessary research work for the commercial side can est be carried out directly by a civilian body severed s far as possible from ordinary departmental administration. This place in Great Britain is filled by the

Side View of the Sopwith Antelope Airplane (at the Left) and One of the Nose of the Machine (at the Right)

Aeronautical Research Committee, formerly the Advisory Committee for Aeronautics, a body which is virually duplicated in its organization and purpose and possibilities of usefulness in this country by the National Advisory Committee for Aeronautics. Secondly, oreign experience emphasizes the value of special competitions for commercial aircraft. There is no doubt that he British competitions aroused more interest among he manufacturers and did more to develop design for pecifically commercial purposes than would an equal mount of money expended on purchases of designs already developed, and it is my opinion that we in America could do nothing more useful to encourage eronautics than to plan to hold such a competition for urely commercial aircraft. The French also have had a competition, but theirs differed a little from the British ne in that the French rules kept the possibility of military need always in mind and made it a condition of ntry that the airplane must be of a type easily and rapdly convertible for use as a bomber.

The French Government has perhaps paid a little less ttention to the establishment of ground services than as the British, but it adopted in September, 1919, an laborate scheme of subsidization of operating comcanies. The subsidy is a maximum for services operating regularly between points at least 200 km. apart and is then equal to one-half of the depreciation based on an assumed life of 400 hr. for an airplane and 267 hr. for an engine. Under this system a service operating with a two-engine airplane carrying 12 passengers and costing $40,000 for the airplane without engine and $10,000 for the engines would receive an award of $75 per hr. of flight. Where the line is less than 200 km. in total length, the hourly award is halved. Additional bonuses are given for the length of voyage without stop, for the power of the engine, for the speed and for the

Side View (at the Left) and View of the Nose (at the Right) of a Farman Goliath Airplane Driven by Two Salmson Engines

useful load carried. Furthermore, the last two bonuses are proportionate to the nature and location of the service, being a maximum for services in the interior of Africa and a minimum for those in continental France. Here again will be noted the desire to use the airplane as a bond of empire. A still further premium is awarded for military value and for ease of conversion for bombing purposes, so that it would be easy for the airplane specified above to receive a total premium of $135 per hr. of flight or about 12 cents per passenger-mile. These premiums are available only for companies wholly French, using airplanes and equipment of French design and construction. To qualify for the premiums it is required that the total number of airplanes owned and kept ready for service as far as possible be at least three times the number actually in use at any given time and that the number of pilots be 50 per cent greater than the number flying on any particular day.

Other countries have done much less to encourage civil aviation. The German Government, owing to the restrictions of the treaty and its own impoverishment, has been unable to give any concrete assistance to German air-transport companies and little has been done by the Government in Italy or any of the smaller States. The Belgian Government is taking steps to give such support as is necessary to insure the establishment of service in the Belgian Congo and the Polish Government, as already noted, is offering a small subsidy to the company operating between Prague and Warsaw.

The Air Convention

The Governments come in contact with commercial aviation not only in extending that assistance which is necessary to keep it going, but also in exercising that measure of control which safety exacts. The control exercised is supposed to be practically uniform throughout the allied countries and those neutrals which have subscribed to the International Air Convention and the League of Nations, being regulated in detail by the terms of the Air Convention, which document provides for the licensing of aircraft and of pilot navigators and engineers, for the conditions to be observed in crossing International boundaries, and for rules of the road and lights and other signals. The Air Convention was originally intended to be a closed corporation, as it prescribed that every contracting State undertook to prevent the flight across its territory of any aircraft belonging to a non-contracting State, but a protocol was drawn up later permitting any State, which so wished,

Nose and Side Views of the Handley-Page Commercial Airplane

to nullify this particular clause, as the neutral states surrounding Germany had naturally protested against being required to bar out German aircraft until such time as Germany should be received in the League of Nations. The points of detail in the Air Convention which are of most interest to us are those dealing with international navigation. It is prescribed that any commercial aircraft of a contracting State shall have the right to cross the borders of any other contracting State without landing therein, subject to the following of such regulations as each State may lay down relative to the prohibition of flying over military or other secret areas. It is further prescribed that an aircraft making a voyage from one State into another shall land at a prescribed customs airdrome and that any forced landing at the end of an international flight shall immediately be reported to the customs authorities. Each State is given the right to restrict traffic between two points within its own borders to aircraft owned by its own nationals and elaborate provisions are laid down against the camouflaging of alien nationality behind the names of native dummy directors. This is, of course, analogous to the provisions of the coastwise shipping acts in force in America and other countries. While the air convention should very much facilitate international travel by air, in practice some difficulties have arisen owing to the present unsettled state of Europe, and commercial aircraft have been forced frequently to land in a contracting State over whose territory the pilot had planned to pass without stop. The convention has, however, very much ameliorated conditions and international intercourse would be quite impossible without some such arrangement.

The Air Convention charges each contracting State with the duty of granting certificates of airworthiness and licenses to operating personnel. The conditions for the licensing of pilots are laid down in detail, the tests not being very difficult, but it is left to each country at least for the present to make its own regulations for the granting of the airworthiness certificate. In England a memorandum has been issued treating in detail of the load factors required in commercial aircraft and of the methods of calculation of stresses, and the design of every airplane flown for hire in the British Isles has to be examined, checked and approved by the Air Ministry. No European State has any intention of permitting, if they can be prevented, such catastrophies due to improper design as have occurred too frequently in the past. Every aircraft flying on Great Britain or any other contracting State is required to carry its official designation in the form of five letters painted on the side of the fuselage and also on the bottom of the lower wing. The first of these five letters designates the nationality of the aircraft, except that in the case of a number of smaller States having the same first letter the nationality is designated by the second letter. In accordance with the terms of the Air Convention, had the United States accepted them in full, every American aircraft would have been required to bear five letters registered at Geneva, the first letter being N. The total set of five letters forms the wireless call-signal of the aircraft.

Passports and Visés

The frequency of international boundary lines in Europe, particularly since the recent redrawing of the map of Central Europe, has both favorable and unfavorable effects on commercial flying. In a flight in which several States are crossed the traveler by air is saved much inconvenience, provided the intentions of the Air Convention are realized and the aircraft is not required to land as it crosses each boundary, as only one visé would be required, whereas one who journeys by rail must have his passport viséd for every country he is to penetrate; a rail journey from Paris to Constantinople, for example, entails weary days of waiting in the ante-rooms of the consulates of the various countries of Central Europe. On the other hand, the delay in waiting for a visé or to secure a passport is a much more important relative fraction of the time of an air than of a land or water journey. The value of being able to go from London to Paris in 2½ instead of 9 hr., for example, is much decreased if two days to secure passport have to be added to the time of both trips. The passport difficulty is fortunately being much ameliorated through the efforts of the League of Nations and other agencies, so that it is now possible for an Englishman having frequent business in Paris to secure a passport and a French visé both of which are good for one year.

Customs Airdromes

As already noted, all aircraft making international journeys must, barring emergencies, land at a customs airdrome. These airdromes are located at Croydon and at Cricklewood for London and at Le Bourget for Paris, and incoming aircraft are handled and their contents examined by the customs officials very much as are ships at a port. Incidentally, several attempts at smuggling by aircraft have already been detected. The Croydon airdrome is especially remarkable for a system of landing lights which indicates the place to land and the wind direction. Lights below glass plates sunk flush with the surface of the field are arranged to form four pairs of parallel lines, and a single switch controls each pair of lines. The pilot is supposed to land between and parallel to the two lines which are switched on. The direction in which the wind is blowing along the lane thus defined is shown by the arrangement of the lights at the ends.

Status of Manufacturers

No consideration of the status of commercial aviation would be complete without some discussion of the relations and the interactions between the operating companies and the industry. In most instances the companies operating in Europe have been distinct from those making the aircraft, although there are several exceptions, such as the Handley-Page, Airco, Zeppelin, Rumpler, and Sablatnig. This separation leaves the manufacturer dependent for support on the sale of airplanes in the open market, assuming that there are no direct Government purchases, and it forces him not only to produce a type which will attract the traveler by air, but also to attract the operating companies, his potential customers, by making aircraft that are durable and economical and easy to repair, and by furnishing prompt service when anything goes wrong; factors some of which have not entered very largely into the calculations of airplane builders up to the present time.

The competition between manufacturers who must depend on a commercial market is certain to be bitter, for not even the greatest optimist can see any prospect of business that will support the number of producers now endeavoring to keep from the wall. The only hope for many of them, particularly those who have not the cap-

ital to stand a long siege and to carry on an expensive publicity campaign throughout the world, lies in the growth of a demand for small airplanes from private individuals, for the demand for new machines from the air-transport services, numerous though these services are, is still very small. In a week of good weather 120 airplanes, most of which are of British manufacture, make the trip between England and the Continent. Allowing three trips per week for each airplane in active service, it can be assumed that 40 airplanes are engaged in cross-Channel transport. If the life of a commercial airplane flying an average of 10 hr. per week is taken as 18 months, the maintenance of the Anglo-Continental air services at their present strength would require the provision of only about 30 new airplanes a year, a small demand on which to rest an industry of the scope of that which grew up during the war. Although there is no doubt of the absolute necessity of increased reliability and durability, any increase in life unaccompanied by at least a corresponding increase in the extent of the commercial use of aircraft, will serve merely to aggravate the difficult situation in which the manufacturers now find themselves. Their only hope lies in constantly continuing expansion of the use of aircraft. For commercial flying to rest on its oars, satisfied with its existing position either now or at any future time, would clearly mean the virtual extirpation of the aircraft industry and be a national danger in that it would put a stop to the manufacture of an article essential for national defense.

Enclosed Cabins

Granting that there is to be bitter competition for such commercial business as exists, it remains to be seen what policy the producer should adopt and what features he should incorporate in his design to appeal to the purchaser. First, as to general layout, an enclosed cabin will be required in all cases in order that flights can be made with comfort to the passengers in all sorts of weather. The cabin must not, however, be made so airtight in the effort to secure warmth that the air inside can become bad. Several enclosed-cabin designs have been notorious offenders in this respect, and I believe that a large majority of the cases of airsickness which occur in straight cross-country flying are at least as chargeable to bad ventilation as to bumps and unsteady motion. The enclosure of the pilot's seat has not found favor in post-war European designs, with one or two exceptions, but there seems to be no very good reason for this, and the pilots who have tried it have found no difficulty in controlling the aircraft from inside the cabin. Another element having an important bearing on the comfort and convenience is the ease of access to the cabin and the freedom of movement inside. No airplane in which the passengers must make their entry by arising through the floor or descending through the roof has any commercial future, nor has any machine in which the cabin is crossed and re-crossed by bracing wires through which the occupants must thread their way. These things are much more important than attractive upholstery, figured walls and window curtains which have attracted so much attention in some recent productions. Fortunately few European machines of the last year offend in respect of accessibility and comfort. The necessity of omitting bracing wires and of putting in the side of the fuselage a door at least 4½ ft. high and without any wires or other members across it, imposes a fuselage constructed of either metal or veneer upon the designer of this type of aircraft, with the preference lying with the latter of these two materials.

Materials of Construction

Reliability requires a decided change from the present type of construction. All-metal construction is still regarded with grave suspicion outside of Germany, and even by many Germans, but metal is certain to be used to a constantly increasing extent in struts, spars, control surfaces and fuselages. In any case, fabric must go, in favor either of metal or of veneer. So long as the present rapid deterioration of the wing covering persists, the airplane cannot be regarded as a finished product for either commercial use or private ownership. It is my belief that the trend in non-military airplanes is toward veneer covering, such as is employed by Fokker on his latest products, rather than toward the metal covering made famous by Junkers and recently adopted in a different form by Short. Another material that has no proper place in large airplanes and has survived by reason of cheapness and simplicity of application, is the rubber in the shock-absorbers. Oleo and hydraulic gears in combination with relatively light steel springs have long been known and there is no reason why they should not have been used, especially on the largest commercial airplanes. Yet another point where change of material is necessary is in the propeller. The wooden propeller goes to pieces with amazing rapidity in rain or hail, and must be replaced by a screw of some more resistant material. Metal propellers are being experimented with extensively in Europe, and at least two, one of steel and one of aluminum, have reached the point of trial in flight. The bakelite propeller seems to fill the bill admirably, but it has not yet found its way across the Atlantic.

Number of Engines

The question of superiority between the single-engined and the multi-engined airplane has not yet been settled, and both types are in regular use. In order that a twin-engined airplane can maintain flight without losing altitude when one engine has been cut off, thus securing that added measure of safety against forced landings with which such craft are commonly credited, it must be very lightly loaded with full power and therefore be uneconomical as a vehicle for transporting useful load. When loaded for efficient commercial utilization it will certainly be impossible to stay in the air with the power reduced 50 per cent. A twin-engined machine which cannot hold the air with one engine cut off has obviously just twice as many chances of being forced to land by engine trouble as has the single-engined design, and a number of the operating companies are accordingly still clinging to the single unit. The easiest way around the twin-engine difficulty is to use light, high-efficiency engines of military type and not run them at full throttle under ordinary circumstances, thus prolonging their life and having a large potential power reserve in each engine to be called on in case of the failure of the other. This arrangement is preferable to the use of heavier and more reliable "commercial" engines run normally at full throttle only on twin-engined machines. The objection to the twin-engined airplane that has just been raised does not apply with nearly so much force when the number of engines is increased to three or four or more, and the commercial airplane of the future must be multi-engined unless it is to work over territory where a forced landing is possible at practically any point. Particularly if flights are to be made at night

or over rough ground such as is found in the African colonies and on the road to the British dominions in the East, a multiplicity of engines will be essential. There is no tendency in any of the allied or neutral states to imitate the common German practice of keeping the powerplants central and gearing several engines together on a single large propeller, and this practice does not appear to offer any special advantages. The arrangement of engines in the Staaken giant is a much more promising development, as the distribution of weight along the span reduces enormously the stresses in the wing structure and makes lighter construction possible. This construction does, however, have the harmful effect of increasing the landing stresses, and such an airplane with cantilever wings, the Staaken is not a true cantilever job, could be landed only on a very smooth field where the several landing gears could be counted on to make contact simultaneously. The airplane with more than two groups of engines built into the wings must, therefore, to gain the full benefit of the distribution of weight, have enough powerplants and reliable enough ones that the possibility of a forced landing in a difficult field can simply be dismissed from the mind. Provision against forced landings in a large commercial aircraft should be so complete that provision for forced landings can be neglected. No naval architect attempts to design an ocean liner so that she can be run on the beach with impunity.

Marine Aircraft

With the total elimination of the forced landing as a factor, it will become safe to make overland journeys of reasonable length in flying boats, and it seems to me inevitable that much of the air traffic of the future will be by marine or amphibious aircraft, because of the ease of finding landing fields near great cities. Nearly all of the world's great centers have their business districts immediately adjacent to a frontage on sea, lake, or river, and the ability to take-off from and land at any waterfront would usually shorten the total time of a journey by at least ½ hr. At the present time the trips from the center of London out to Croydon and from Le Bourget into Paris by automobile consume almost half as much time as the whole journey from Croydon to Le Bourget by air. Already there has been much serious discussion, although no official action has been taken, of setting aside a strip of the Thames as a landing-place for aircraft, and it was presumably with an eye to the saving of time at the termini of intercity journeys that the Air Ministry undertook to encourage the design of amphibious aircraft by providing a special class for them in the civil aircraft competitions of the past summer.

Transferable Packing Cases

The cargo of an airplane is small enough so that it can often be completed with a single consignment, or at least with a group of shipments for the same destination, and a company has recently been formed in London to carry express exclusively, especially over long distances, packing the consignment in a case designed simply to drop into the cargo space of the airplane used and transferring this case and its contents bodily from one machine to another of similar type at the end of each stage of the flight, thus saving the time required to re-fuel and inspect the machine just finishing its flight and starting the express on its way again with scarcely more delay than was involved in a change of mounts and a transfer of the mail pouch in the pony express of the old West. Although this scheme may work out satisfactorily, there are no two points in the Eastern hemisphere between which it could be used so profitably as between our own Eastern and Western coasts.

The pictures which accompany this paper show a few of the types of airplane most commonly used in transport and "taxi" service.

CONFERENCE ON AERONAUTICAL SAFETY CODE

A CONFERENCE was held in Washington recently to consider the development of an aeronautical safety code for which the Bureau of Standards and the Society of Automotive Engineers have been designated as the joint sponsors by the American Engineering Standards Committee. This conference was attended by representatives of the War, Navy and Post Office Departments, the National Advisory Committee for Aeronautics, the National Safety Council, the Manufacturers' Aircraft Association and the Insurance Underwriters, as well as representatives of the two sponsors and the American Engineering Standards Committee.

It was the sense of this conference that a safety code ought to be developed without delay and that a committee should be formed at once to include representatives of all organizations interested in this subject as well as those which were present at the conference. Invitations have, consequently, been extended to various other organizations which are interested in the formulation of such a code.

BRITISH AND AMERICAN BANK DEPOSITS

BETWEEN June, 1914 and June, 1919, deposits in American banks increased about $19,000,000,000, or 88 per cent, while from December, 1914, to December, 1919, there was an increase of approximately £1,400,000,000 in British bank deposits, exactly the same percentage of increase as in the United States.—Bankers Trust Co.

Problems Involved in Developing Engine Gasoline Specifications[1]

By E. W. Dean[2]

ONE of the vital problems associated with the production, sale and utilization of engine gasoline is the development of practical specifications for quality and grade. The importance of this problem has been thoroughly recognized and the use of gasoline specifications is already an established practice. Large users, among which the Federal Government is a notable example, have adopted more or less complete sets of requirements for grades and quality of internal-combustion engine fuel. Transactions within the petroleum industry frequently involve specifications and last, but not least important, is the fact that a number of state and municipal legislative bodies have adopted or are considering the adoption of regulations controlling the quality of internal-combustion engine fuel dispensed to the general public.

The majority of the problems involved in the development of practical specifications for internal-combustion engine gasoline can be grouped in three general classes, as follows:

(1) The recognition of essential properties
(2) Definition of essential properties in terms of adequate laboratory tests
(3) The adoption of limits that express satisfactory quality in terms of the accepted laboratory tests

General Properties of Satisfactory Engine Gasoline

The following list of requirements is believed to indicate the general properties of satisfactory motor gasoline.

(1) Should not be unnecessarily dangerous in storage and handling and should not be subject to excessive evaporation losses
(2) Should not contain solid or non-combustible material
(3) Be free from constituents that corrode or injure the parts of the equipment in which it is stored or used
(4) Have a minimum content of constituents that tend to form solid or gummy deposits either in storage receptacles or in internal combustion engines
(5) Neither engine gasoline nor its products of combustion should possess markedly disagreeable odors
(6) Should have a properly limited and balanced range of volatility

There is no question as to the desirability of including in specifications a clause that will preclude the transportation, sale, and use of gasoline that is unnecessarily dangerous and that is subject to excessive losses in storage and handling. The accuracy and adequacy of the present vapor-pressure test[3] is, however, not above question and there is a clear necessity for its improvement. I understand that a modification of this test is being studied at the present time.

The presence of solid or non-combustible material can be determined by optical inspection of a properly taken sample. Gasoline should, of course, be perfectly transparent and homogeneous.

The problem of testing gasoline for corrosive constituents is one that cannot be adequately discussed since there is a notable lack of information regarding the causes and mechanism of this phenomenon and it is not believed that any or all of the present tests furnish conclusive evidence. The acidity test[4] is believed to offer a reliable means of detecting one type of corrosive constituent. The copper-dish evaporation test[5] is not satisfactory for the examination of internal-combustion engine gasoline, but a corrosion test under consideration by the American Society for Testing Materials and involving the same general principle can undoubtedly be used to detect another type of corrosive constituents. In general, however, it appears that the general problem of corrosive properties deserves more careful investigation than it has received.

One of the most troublesome phenomena in the operation of internal-combustion engines is the occurrence in cylinders and manifolds of carbon deposits. These are sometimes attributed to the use of lubricating oil of improper grade or unsatisfactory quality, but a fair proportion of evidence seems to indicate that the gasoline is either directly or indirectly the offending agent. It is by no means certain that the entire cause of the trouble is failure to effect proper dispersion of the fuel in the air mixture which goes into cylinders.

There is at present no satisfactory laboratory test indicating whether a particular sample of gasoline has an undue tendency to deposit solid material either in the manifolds and cylinders of internal-combustion engines or in storage tanks or pipe connections. The copper-dish evaporation test has a certain degree of application in this direction but it has been shown by some experiments[6] made in Bureau of Mines laboratories that it can be applied satisfactorily only to grades of gasoline, such as airplane gasoline, that can reasonably be expected to give no deposits. The test as at present outlined does not seem satisfactory to use with limits on the maximum allowable quantity of deposit.

It is believed that there is need of investigating this general problem and determining first whether there is need for a specific test for the property of forming solid deposits and second what this test should be. Work along this line has already been undertaken by the Bureau of Mines but the subject is so broad that it is believed that other research organizations can profitably

[1] Published with the permission of the Director of the Bureau of Mines. Abstract of a paper read before the 1921 annual meeting of the American Society for Testing Materials.

[2] S. M. S. A. E.—Petroleum chemist, Bureau of Mines Experiment Station, Pittsburgh

[3] See report of the Chief Inspector of the Bureau of Mines on the Safe Transportation of Explosives and Other Dangerous Articles, February, 1916, pp. 27-30, and Bureau of Mines Technical Paper No. 214 entitled Motor Gasoline, Properties, Laboratory Methods of Testing and Practical Specifications, by E. W. Dean, pp. 26-27.

[4] See Bureau of Mines Technical Paper No. 214 entitled Motor Gasoline, Properties, Laboratory Methods of Testing and Practical Specifications, by E. W. Dean, p. 17.

[5] See report of Committee on Standardization of Petroleum Specifications, pp. 3-4.

[6] Results not yet published.

give it attention with the hope that the sum of the knowledge derived may yield a satisfactory answer.

Good odor is an important but, fortunately, not absolutely essential property of internal-combustion engine gasoline.

The important property of distillation range is one for which a satisfactory laboratory test has been developed and adopted. Some of the details of apparatus and procedure are still a fruitful subject for argument, but the tentative standard method of the American Society for Testing Materials[7] represents the agreement and compromises of men and organizations that have had the benefit of a very considerable amount of practical experience with the testing of gasoline.

Specification Limits

The most generally familiar set of gasoline specifications is that adopted by the Committee on Standardization of Petroleum Specifications and published in Bulletin No. 5 of that committee.[8] The specifications for engine gasoline include requirements for distillation ranges that place maximum limits on the temperatures read for the first drop, 20, 50 and 90-per cent marks and the dry point. The particular points selected for specification limits were carefully chosen and have not apparently been subject to particular criticism. The actual temperature limits for the first drop and 20 and 50-per cent points seem likewise to be reasonably satisfactory to both producers and consumers of internal-combustion engine gasoline. The limits for the 90-per cent mark and the dry point are the ones concerning which authorities and alleged authorities are in disagreement and which can be profitably discussed in the present connection.

A great number of refiners have discovered that they can produce gasoline which satisfies the dry-point clause with an ample margin of safety and still fails to meet the 90-per cent point requirement. This detail has been regarded as a serious flaw in the specifications and is so fruitful a source of argument that I take this occasion to point out the significance of this apparent lack of balance in the two limits. Determinations of the dry point have been and probably still are likely to involve a considerable possibility of disagreement between the results reported by different operators. The 90-per cent mark, on the other hand, is relatively easy to check. With this fact in view the members of the specifications committee thought it advisable to make the 90-per cent mark the effective upper distillation limit and use the end-point limit simply as insurance against careless or inefficient refining methods. The apparent discrepancy between these limits is, therefore, intentional and, on the basis of the evidence considered by the committee, justifiable.

[7]See Test D-21T of the American Society for Testing Materials
[8]See The Journal, March, 1921, p. 219.

A more important difference of opinion concerns the actual limits, of which, as has just been indicated, the 90-per cent mark is usually the controlling one. A number of representatives of the refining industry have claimed that this is too low and therefore a detrimental influence on account of the present economic necessity of securing maximum yields of internal-combustion engine fuel from an inelastic supply of crude petroleum. Individual users are more or less inclined to the opinion that all present-day gasoline is unsatisfactory and that some products are worse than others. The most intelligent representatives of the consuming public are perhaps the men who design and supervise the building of internal-combustion engines and their majority opinion seems to be that gasoline meeting the present Government specifications may contain appreciable percentages of constituents that are not efficiently utilized by the average engine.

I cannot venture any opinion as to the relative merits of these opposing views and must, therefore, point out that the Government specification is actually a compromise and not the result of biased views or ignorance. The following suggestions are, however, offered as an indication of the basic principles that should cover the selection of limits for any specification that is likely to receive widespread recognition as a standard for the quality of internal-combustion engine gasoline:

(1) Specification limits should be selected as an agreement or at least a compromise between the views and thoroughly representative groups of authorities from the producers and the users
(2) Reasonable uniformity should be maintained in the quality of the gasoline produced by different refining companies and in different parts of the country. The influence of the law of supply and demand should be reflected in the price of the commodity rather than its quality
(3) Radical changes in the general quality of internal combustion engine gasoline should, if possible, be agreed on and announced a reasonable length of time in advance of the date when the modification is to be made effective. This does not concern the normal seasonal variation in quality but rather such changes as are likely to affect the efficiency of the average existing engine. If such an arrangement could be effected it would be possible for automotive engineers to design and build engines to "fit" a known quality of gasoline and also permit the development of supplementary devices to improve the operating efficiency of engines already in use

These suggestions obviously indicate the necessity of cooperation between representatives of the producers and consumers. Such cooperative effort is already being organized and, needless to say, the Bureau of Mines commends all possible activity in its behalf.

Merits of Different Splices for Airplane Wing Beams

By H. D. Frary[1]

Illustrated with Drawing

EARLY in the war the great demand for airplane spruce led to a shortage of clear, straight-grained pieces long enough for airplane wing beams. This shortage made it necessary to allow splicing; consequently, early in 1918, specifications for several different types of splices were drawn up by the airplane engineering division of the Signal Corps. To determine the relative merits of these and other types of splice for wing beams, the United States Forest Products Laboratory at Madison, Wis., began in March, 1918, the tests described.

As the tests progressed, other problems developed or were suggested from various sources. At first the investigation was confined to solid and two-piece laminated beams, such as were being used in the actual construction of airplanes; but when the Air Service decided to investigate the built-up three-piece I and box types, Nos. 21 to 35, with a view to putting them into production, the Laboratory began a study of splices in these types of beam also. Altogether, the results here presented represent nearly a year's work, comprising tests of 670 spliced beams of 51 different kinds, together with 345 matched unspliced beams. The results obtained are by no means the last word on splices in wing beams, as many points have developed that require further investigation, but the tests have established certain conclusions of considerable importance.

Material and Construction of Beam

All the beams were made in the Laboratory carpenter shop of kiln-dried Douglas fir and Sitka spruce. Results of tests on any beams found to be of stock unsuitable for airplane use were rejected from the averages and from the tabulated results. Certified hide glue which was spread by hand was used and hand clamps were employed to hold the parts together. The gluing on the first set of beams, namely, the Douglas fir beams of types Nos. 3, 10, 11, 13, 14, 15, 16, 19 and 20, was probably not quite so expertly done as was that on other beams made up later.

To determine the efficiency of a splice an unspliced beam was always matched to each spliced beam and to compare the relative efficiencies of two different types of splice each spliced beam of the one type was always matched to the corresponding spliced beam of the other type. This matching was accomplished by cutting the beams side by side from the same plank.

The construction of the spliced beams of each type is clearly shown in drawings Nos. 1 to 35 of the accompanying illustration. Solid and two-piece wing beams are usually routed out to form an I-section, but for greater strength it is customary to leave the beams unrouted at the splice. For test purposes, however, the beams of types Nos. 1 to 20, both spliced and unspliced, were made rectangular in section throughout. Consequently, the efficiencies of splices are based on the unrouted unspliced beam.

The beams were tested in cross-bending with loads at the third-points,[2] the span being 60 in. for types Nos. 1 to 20, and 72 in. for types Nos. 21 to 35. The splices being at the center were subjected to the maximum moment but not to shear stress. Following the beam tests, specimens were cut from each beam for tests in compression parallel to the grain and for specific gravity and moisture determinations. The purpose of these tests was to check up the matching and to give a measure of the quality of material. A summary of the principal data and results is given in Table 1 with references to the various splices.

Kind and Plane of Scarf

Obviously, splices should be of comparatively simple design and easy to make. The greater the degree of skill required and the more complicated the process, the higher the labor costs and the more danger of poor workmanship with a resulting lack of reliability. Probably in a large measure for these reasons, the plain sloped scarf, with or without dowels or bolts, has been very generally adopted for wing-beam splices. Of the 35 types discussed here, 32 are based on the plain sloped scarf. Three other kinds of scarf, types Nos. 9, 10 and 19, were tested.

Type No. 9 has a sloping scarf like type No. 3, but with two three-ply plywood splines inserted. If the results for these two types in Douglas fir are compared it is seen that the efficiency of the splice with splines was consistently lower than that of the plain splice, the averages being 54.6 and 73.0 per cent respectively. Apparently, cutting out the beam for the insertion of the splines weakens it considerably more than the splines strengthen it.

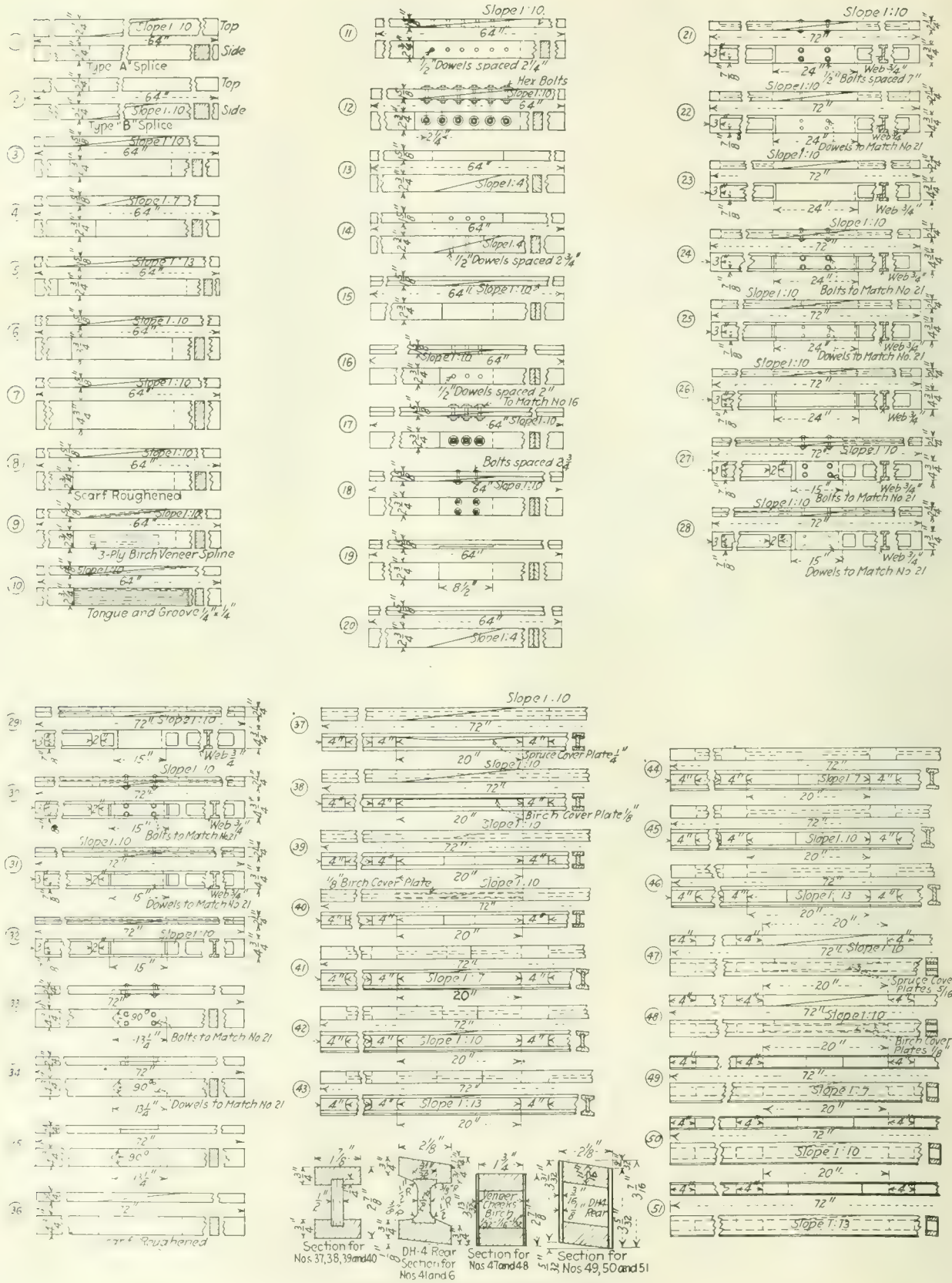
Type No. 10 is a splice consisting of close-fitting ¼-in. tongue-and-groove joints at a slope of 1 in 10. The average efficiency obtained was 75.9 per cent. This is slightly greater than that of the plain splice of the same slope, No. 3, and the same material, Douglas fir, which was 73 per cent, but the minimum values are practically the same. As a matter of fact, the workmanship on type No. 9 was probably somewhat better than on the fir beams of type No. 3, as already stated. Apparently this tongue-and-groove splice is no stronger than the plain splice, No. 3, and it is, of course, more difficult to make.

The third type of splice other than a plain sloped scarf is the half-lap scarf illustrated for a two-piece beam in type No. 19. In this splice the principal glued surface is parallel to the sides of the beam. If the efficiency of No. 19 is compared with that of No. 15, it is seen that this type is decidedly inferior to the plain sloped scarf of the latter type.

The conclusion from these tests on different kinds of

[1] Engineer, forest products laboratory, Department of Agriculture, Madison, Wis.

[2] A few tests made to determine the difference in strength of a splice under third-point and center loading disclosed no variation whatever.



VARIOUS SPLICES AND BEAMS TESTED

The Numbers in the Circles Opposite Each Splice or Beam Section Correspond to Those in the First Column of Table 1

TABLE 1—TESTS OF AIRPLANE WING BEAM SPLICES

One and Two-Piece Rectangular Beams

Type No.	Pairs of Matched Beams[1]	Material	Efficiency Ratio of Spliced to Unspliced Beams, per cent: Minimum	Maximum	Average	Length of Splice, in.	Glue Area of Splice, sq. in.	Relative Efficiency, per cent: Compared to Type No.	Minimum	Maximum	Average	Routing and Filler Blocks at Splices	Location of Splice	Slope of Splice	Splice Failures, per cent
1	...	Spruce	...	...	...	22.5	50.8	...	...	...	...				
2	10	Spruce	...	...	...	22.5	50.8	1	57.1	209.5	122.0				
3	6	Fir	49.5	88.0	73.0	16.2	44.9	...	...	...	...				
	10	Spruce	70.2	103.8	91.3	16.2	44.9	...	...	...	...				
4	8	Spruce	...	...	...	11.4	31.6	3	61.0	121.5	88.8				
5	8	Spruce	...	...	...	21.1	58.3	3	87.7	121.7	100.4				
6	10	Spruce	82.4	127.3	102.6	16.2	61.2	...	...	...	...				
7	10	Spruce	71.9	111.6	95.6	16.2	77.6	...	...	...	...				
8	10	Spruce	...	...	...	16.2	44.9	3	76.8	115.8	99.7				
9	8	Fir	41.9	59.5	54.6	16.2	68.3	...	...	...	...				
10	10	Fir	50.0	100.0	75.9	16.2	85.7	...	...	...	...				
11	9	Fir	72.5	107.0	86.8	16.2	44.9	...	...	...	...				
	7	Fir	...	...	...	16.2	44.9	3	78.5	119.1	93.4				
	10	Fir	...	...	...	16.2	44.9	3	72.7	159.0	110.4				
	9	Spruce	54.5	105.5	88.3	16.2	44.9	...	...	...	...				
	9	Spruce	...	...	...	16.2	44.9	3	68.4	117.8	97.5				
12	10	Spruce	78.6	116.1	92.6	16.2	44.9	...	...	...	...				
	10	Spruce	...	...	...	16.2	44.9	3	78.6	128.5	102.1				
13	7	Fir	17.0	53.1	33.7	11.0	18.4	3	33.3	57.1	46.8				
14	9	Fir	19.6	61.4	38.6	11.0	18.4	...	...	...	...				
15	10	Fir	77.7	105.5	90.0	8.1	22.4	...	...	...	...				
	9	Spruce	71.5	114.0	93.2	8.1	22.4	...	...	...	...				
16	10	Fir	72.0	123.5	100.2	8.1	22.4	...	...	...	...				
	6	Fir	...	...	...	8.1	22.4	15	75.2	165.6	110.8				
	10	Fir	...	...	...	8.1	22.4	15	64.2	125.0	96.0				
	9	Spruce	66.2	104.6	83.0	8.1	22.4	...	...	...	...				
	10	Spruce	...	...	...	8.1	22.4	15	71.2	121.8	90.6				
17	9	Spruce	54.0	107.8	86.4	8.1	22.4	...	...	...	...				
	10	Spruce	...	...	...	8.1	22.4	15	54.0	131.3	93.5				
18	6	Fir	61.5	82.7	72.9	8.1	22.4	...	...	...	...				
	9	Fir	59.5	81.5	72.9	8.1	22.4	...	...	...	...				
19	9	Fir	58.8	98.7	81.0	8.5	23.4	...	...	...	...				
20	10	Fir	39.1	86.5	66.6	11.0	9.2	...	...	...	...				

Navy Beams[4]

21	3	Spruce	72.5	96.0	84.3	22.5	107.3	...	...	...	...	Unrouted			
	2	Spruce	87.5	108.0	97.8	22.5	107.3	...	...	...	...	Unrouted			
22	5	Spruce	79.5	114.6	97.2	22.5	107.3	...	...	...	...	Unrouted			
23	5	Spruce	93.8	146.8	112.6	22.5	107.3	...	...	...	...	Unrouted			
24	5	Spruce	79.5	126.3	93.8	22.5	62.1	...	...	...	...	Routed, blocks glued in			
25	5	Spruce	88.4	109.5	97.7	22.5	62.1	...	...	...	...	Routed, blocks glued in			
26	4	Spruce	75.7	126.0	100.0	22.5	62.1	...	...	...	...	Routed, blocks glued in			
27	3	Spruce	104.4	145.2	119.9	11.2	53.6	...	...	...	...	Unrouted			
28	3	Spruce	97.2	116.0	109.3	11.2	53.6	...	...	...	...	Unrouted			
29	5	Spruce	71.9	105.6	87.4	11.2	53.6	...	...	...	...	Unrouted			
30	4	Spruce	73.2	102.3	93.6	11.2	53.6	...	...	...	...	Routed, blocks glued in			
31	5	Spruce	99.0	109.8	104.9	11.2	53.6	...	...	...	...	Routed, blocks glued in			
32	5	Spruce	81.5	100.0	93.4	11.2	53.6	...	...	...	...	Routed, blocks glued in			
33	5	Spruce	33.6	43.9	39.5	13.2	52.7	...	...	...	...	Unrouted			
34	5	Spruce	31.7	53.0	38.2	13.2	52.7	...	...	...	...	Unrouted			
35	5	Spruce	28.9	51.6	36.5	13.2	52.7	...	...	...	...	Unrouted			
36[5]	5	Spruce	69.0	119.3	90.2	22.5	107.3	...	...	...	...	Unrouted			
	5	Fir	87.2	100.0	93.4	22.5	107.3	...	...	...	...	Unrouted			

Built-up Beams

37	6[6]	Spruce	105.2	125.0	112.2	...	...	...	...	...	...	Flange	1 in 10	17
38	7[6]	Spruce	93.8	120.0	105.5	...	...	...	...	...	...	Flange	1 in 10	14
39	5	Spruce	100.0	104.1	102.3	...	...	...	...	...	...	Web	1 in 10	0
40	5	Spruce	93.0	109.6	101.2	...	...	...	...	...	...	Web	1 in 10	0
41	9[6]	Spruce	71.4	103.4	94.3	...	...	...	...	...	...	Tension Flange	1 in 7	67
42	10	Spruce	87.9	111.9	97.0	...	...	...	...	...	...	Tension Flange	1 in 10	33
43	10	Spruce	80.6	108.3	97.6	...	...	...	...	...	...	Tension Flange	1 in 13	0
44	10	Spruce	79.4	110.7	94.2	...	...	...	...	...	...	Web	1 in 7	0
45	10	Spruce	94.4	113.1	99.2	...	...	...	...	...	...	Web	1 in 10	0
46	10	Spruce	89.5	120.0	101.0	...	...	...	...	...	...	Web	1 in 13	0
47	5	Spruce[7]	85.9	138.1	103.7	...	...	...	...	...	...	Tension Flange	1 in 10	40
	5	Spruce[7]	71.5	136.3	102.2	...	...	...	...	...	...	Compression Flange	1 in 10	20
48	6	Spruce[7]	63.4	124.0	89.5	...	...	...	...	...	...	Tension Flange	1 in 10	50
	4	Spruce[7]	67.3	104.9	81.9	...	...	...	...	...	...	Compression Flange	1 in 10	50
49	9	Spruce[7]	44.0	122.8	77.6	...	...	...	...	...	...	Tension Flange	1 in 7	78
50	10	Spruce[7]	53.1	117.8	92.6	...	...	...	...	...	...	Tension Flange	1 in 10	30
51	10	Spruce[7]	85.0	159.3	104.5	...	...	...	...	...	...	Tension Flange	1 in 13	20

See page 136 for footnotes.

scarf is that the general practice of using the plain sloped scarf is justified, since none of the other types or modifications tested gave better results, and all are more difficult to make.

Shall the splice be across the top of the beam or across the side? That is, shall the plane of the scarf be perpendicular to the top or to the side face of the beam? To compare these two types, called for brevity type A and type B, respectively, 20 beams in matched pairs like Nos. 1 and 2 were made and tested. The beams were square and, aside from the splices, as much alike as they could be made. The results of the tests indicated that the splice across the side was more efficient than the splice across the top, the average relative efficiency being 122 per cent. There were, however, three erratic values, two high and one low. The beams from which these erratic ratios were derived were carefully inspected without finding any justification for rejecting the results. The omission of the percentages derived from these three would give an average percentage of 107.6. The fact that 9 out of the 10 pairs, or, if the three erratic values be rejected, 7 out of 7 pairs of beams gave percentages in excess of 100 was a further indication of the superiority of the type B over the type A splice in square beams. The data was not regarded, however, as furnishing a sufficient basis for a statement of the amount of this superiority.

To obtain more conclusive evidence on this point, further tests of these two types of splice were made. Sixty additional beams like the above were made up, matched in sets of 3, 20 unspliced, 20 spliced across the top and 20 spliced across the side. Special care was exercised in selecting the material and in making up these beams. The two spliced beams of each matched set were cut side by side and so as to be from the same annual rings. The unspliced beam was cut next to one of the spliced beams. The two spliced beams of each set were made by the same man and glued at the same time, so as to eliminate the personal equation and any difference in different mixes of glue. The three beams of each set were tested with annual rings in the same direction, and the direction of rings in the different sets was varied, as many with rings horizontal as vertical, to eliminate any possible influence of the direction of the rings upon the average results.

The results of these tests, contrary to expectations based on the tests previously made, gave almost exactly the same average efficiencies for the two types; that is, the relative efficiency was 100 per cent. One very interesting fact seemed to be shown by these tests, namely, that the direction of the annual rings has an effect upon the efficiency of the splices. Of the eight sets of beams in which the annual rings were horizontal during the test, the results from six sets showed higher efficiencies for the type A splice than for the type B splice, and the average relative efficiency, type B divided by type A, was 95 per cent. On the other hand, of seven sets of beams with rings vertical, none showed a greater efficiency for type A than for type B, and the average relative efficiency was 107 per cent. Apparently, a splice is somewhat stronger when it cuts across a tangential face than when it cuts across a radial face of a beam. An examination of the 10 pairs of beams previously tested showed that the superiority of type B over type A in these tests could be partly, if not wholly, accounted for by the direction of the rings. The conclusion is reached, therefore, that in square beams splices across the top and across the side are equally efficient.

With rectangular beams it is somewhat different. In a square beam, a type A splice and a type B splice of the same slope have the same glued area and the same length. In a rectangular beam, splices of types A and B, if of equal slope, have the same glued area but are not the same in length; for example, in a beam twice as high as it is wide, the type B splice across the side would be twice as long as the type A splice across the top. Presumably the shorter splice is preferable. The question then arises: If splices of an equal length in rectangular beams are assumed, which is the more efficient, type A or type B? Since the two types are equally efficient in square beams it is natural to expect that in rectangular beams the splice which has the greater glued area will be the more efficient. In other words the splice should cut across the narrower face of the beam; that is, type A or B should be used, according as the height-width ratio is greater or less than unity.

A check on this conclusion is afforded by a comparison of the efficiencies of splices Nos. 4 and 13 with No. 3. The scarf of splice No. 4, type A with a slope of 1 in 7, has practically the same length as that of No. 13, type B with a slope of 1 in 4. No. 4 was 89 per cent as strong as No. 3, while No. 13 was only 50 per cent as strong; that is, the type A splice was much superior to the type B. This is as would be expected, since the height-width ratio of these beams is greater than unity. A further check is obtained by comparing two two-piece beams No. 20 with a type B splice with No. 15 having a type A. Here the length of scarf is in favor of No. 20; nevertheless, the splice was only 66.6/90 or 74 per cent as strong as No. 15. As practically all wing beams are higher than they are wide, it may be stated as a general rule, to which there may be an occasional exception, that solid and two-piece wing beams should be spliced diagonally across the top of the beam, that is, the plane of the scarf should be perpendicular to the top of the beam.

The question now arises: What is the best slope for the scarf of a plain type A splice? If splices Nos. 4 and 5 are compared with No. 3, it is seen that No. 4 with a slope of 1 in 7 was 11 per cent weaker than No. 3 having a slope of 1 in 10 and No. 5 with a slope of 1 in 13 was practically the same as No. 3 in strength. We conclude that for spruce beams with high-grade glue and good gluing the efficiency is increased very little by using smaller slopes than 1 in 10.

Splices Nos. 6 and 7 having a slope of 1 in 10 and the plane of the splice vertical were tested to get information

FOOTNOTES FOR TABLE 1 ON PAGE 135

[3] In every case 10 pairs of matched beams were made and tested, but some beams had to be rejected on account of defective material.

[4] All unspliced beams except the first three of type No. 21 were routed in the middle section as well as in the end sections, but these three were left unrouted in the middle section by mistake. The beams to match these spliced beams were like the latter in dimensions and routing, but for types Nos. 29 to 32 the unspliced beams were, of course, routed in the middle section. Five pairs of beams were tested for each type of splice, but some had to be rejected on account of defective material. With the exception of types Nos. 33 to 36 these tests do not give the real efficiencies of the splices because most of the beams failed in the routed part outside the splice.

[5] The efficiency ratio for type No. 36 is that of the roughened to the smooth scarf instead of the ratio of the spliced to the unspliced beam as in all other cases.

[6] Ten pairs of beams were tested, but some of the results were rejected on account of defective material.

[7] The checks of these beams were birch-poplar-birch plywood

concerning the difference in the efficiency with a variation in the height-width ratio. These can be compared with types Nos. 1 and 3. The ratios of height to width for splices Nos. 1, 3, 6 and 7 are respectively 1.0, 1.7, 2.3, and 2.9 and the corresponding average efficiencies obtained for Sitka spruce are 99.6, 91.3, 102.6 and 95.6 per cent. The third efficiency is evidently too high, for it indicates that the spliced beams were slightly stronger than the matched unspliced ones, although three of the spliced beams showed glue failures under test. The first efficiency also seems too high. The figures show no consistent relation and a larger number of tests would be necessary to determine whether there really is any relation between the height-width ratio and the efficiency.

There seems to be a marked difference of opinion in regard to the effect of roughening the scarf of a splice; many practical men insist that this treatment increases the strength of the splice materially. To test this point, 10 spruce beams, spliced like No. 3 were matched to 10 beams spliced in the same way except that the scarfs were roughened with a toothing plane, No. 8. The average relative efficiency obtained by dividing the roughened splice by the smooth is 99.7 per cent. Corresponding tests on 10 pairs of beams of larger size, 2¼ x 4¾ x 76 in., half spruce and half fir, gave average relative efficiencies of 90.2 and 93.4 per cent respectively. Evidently, roughening the scarf of a splice does not increase its strength. These results agree very well with tests recently made at the Laboratory on the shearing strength of scratched or roughened glued joints in hard maple In these tests also the scratched joints were slightly weaker, on the average 2.5 per cent, than the smooth joints.

Value of Dowels and Bolts

In making doweled and bolted splices, a plain splice was first made in each beam. After the glue had set, the holes were bored and dowels were glued in or bolts were inserted. Dowels were of the same material as the beams. Bolts were tightened down as much as possible without injuring the wood. Since the boring of holes undoubtedly weakens a beam, this question arises: Do the dowels or bolts strengthen the beam more than it is weakened by the holes?

The evidence on the effect of dowels in one-piece beams, as shown in Table 1, is somewhat conflicting. The first tests gave, for the efficiency of the doweled splice in Douglas fir, 86.8 per cent as against 73 per cent for the undoweled splice, or 119 per cent for the relative efficiency of doweling. Later tests on fir gave 93.4 per cent and 110.4 per cent for the relative efficiency of doweling. The average of the three is about 108 per cent; that is, the evidence is in favor of the doweled splice. In Sitka spruce, on the other hand, the doweled splice was slightly less efficient, 97.5 per cent, than the plain splice. On a type B splice, Nos. 13 and 14, the efficiency of dowels was 38.6 per cent as against 33.7 per cent without, a slight difference in favor of the dowels. From all this evidence, even though it is somewhat conflicting, it can safely be concluded that the influence of dowels on the efficiency of splices in one-piece beams is small. The results from tests of splice No. 12 with bolts indicate that the same conclusion may be drawn in regard to bolted splices in one-piece beams.

In the two-piece beams, also, the evidence for and against dowels is conflicting. In fir, the first series of tests on doweled splices, when compared with results for the spliced beams without dowels, gives 100.2/90 or 111.3 per cent for the relative efficiency of doweling. The corresponding relative efficiencies for the other two series of tests with fir are 110.8 and 96 per cent, giving an average of 106 per cent. On the other hand, the tests with spruce give only 90.6 per cent relative efficiency. The evidence seems to indicate that the dowels added to the strength of two-piece fir beams but reduced the strength of similar spruce beams. This, as well as the somewhat similar results in one-piece beams, may be due to the fact that the glue does not hold so well in Douglas fir as in Sitka spruce, and that the dowels are brought into play to a greater extent in the fir beams.

Nos. 17 and 18 are bolted splices in two-piece beams. In No. 17 the bolts were located along the neutral surface in the same way as the dowels in No. 16 and were of the same size, ½ in. In No. 18 the bolts were ⅜ in. and not on the neutral surface. No. 17 was Sitka spruce and No. 18 Douglas fir. Both types show efficiencies considerably below those of the plain splice. Evidently the bolts weakened the splice instead of strengthening it. The particularly poor showing for No. 18 is probably due to the fact that failure often started by crushing or splitting of the wood at the bolt-holes on the compression side. As the bolts are comparatively incompressible, a distortion of the stresses in their neighborhood occurs.

The most common argument in favor of dowels and bolts is that, if the glue fails, the dowels or bolts will hold the beam together, or at least prevent a sudden collapse of the beam without warning. If the dowels or the bolts will hold a wing beam together long enough after the glue fails for the aviator to reach the ground in safety, their use is more than justified. To obtain data on this point, five Sitka spruce beams of each of the types Nos. 11, 12, 15, 16 and 17, were made up exactly like the beams previously tested except that no glue was put on the scarf of the splice. They were matched to unspliced beams as in previous tests and thus the efficiencies of the doweled and bolted splices without glue on the scarfs were obtained. The results are summarized in Table 2.

TABLE 2—COMPARATIVE EFFICIENCIES OF BOLTED AND DOWELED SPLICES

Beam	Type of Splice	Type No.	Efficiency, per cent Minimum	Maximum	Average
One-Piece	Doweled	11	8.8	17.1	13.1
One-Piece	Bolted	12	17.2	21.6	18.7
Two-Piece	Plain	15	27.8	60.1	46.0
Two-Piece	Doweled	16	47.1	64.1	58.0
Two-Piece	Bolted	17	54.2	75.0	69.0

Evidently, in one-piece beams, a doweled or bolted splice without glue on the scarf has very little strength, less than 20 per cent of that of the unspliced beam. In two-piece beams with a splice in one lamination, dowels or bolts keep up the strength to 60 or 70 per cent of that of the unspliced beam.

It is evident that dowels and bolts do not come into action to any great extent unless the glue fails in the splice; that is, they do not aid the glue or prevent glue failures. If the glue fails, the dowels or bolts are at once brought into play. Acting alone, the bolts contribute more strength than the dowels, but in either case the contribution is comparatively small. In one-piece beams this small contribution can be of no practical value if the glue fails under load for the beam will collapse immediately in spite of dowels or bolts, but in two-piece beams the added strength due to the dowels or bolts, after the glue has failed under load, may be sufficient to hold the beam together and hence, to justify their use. Moreover, if the splice in a wing beam is at a point of contraflexure

or low moment and the glue should fail entirely because of its poor quality, or the action of moisture, or for some other reason, the dowels or bolts would doubtless be strong enough to hold the two parts together and thus make their use advisable.

Although the results, on the whole, seem to favor bolts over dowels, nevertheless, dowels are preferable for the following reasons:

(1) The bolts are so hard and unyielding that the continual working and straining of the parts soon crushes the wood around them and makes them worse than useless. For the same reason wooden trenails are preferred to bolts or spikes in shipbuilding
(2) The dowels, on the other hand, will bend and give as the parts are stressed without injuring them.
(3) Shrinking of the wood on account of its drying out may cause the bolts to become loose and hence of little value
(4) The initial tightening of the bolts or subsequent tightening on account of swelling of the wood is likely to crush the wood and reduce its strength
(5) Bolts add to the weight

Splices in Three-Piece I-Beams

Splices Nos. 21, 22, 25 and 27 were in the flanges of three-piece I-beams. In the first two the type A splice was used and reinforced with cover-plates. These cover-plates made the spliced beams stronger than the unspliced ones; consequently, they were not used in later tests. It was also decided to use the type B splice instead of type A, since the height of the flange is less than the width. In Nos. 25 to 27, then, the type B splice was used without reinforcement of any kind. These beams were tested to determine the best slope for such a splice, the slopes used being 1 in 7, 1 in 10, and 1 in 13 respectively. If the results shown in Table 1 are compared, it will be seen that the average efficiencies developed for splices with slopes 1 in 10 and 1 in 13 were practically the same, 97 per cent; while the efficiency for a slope of 1 in 7 was somewhat less. The conclusion is that with good gluing a slope of 1 in 10 is sufficient to develop practically the full strength of the section.

Splices Nos. 23, 24 and 28 to 30 were type A splices in the webs of three-piece I-beams. In none of these beams was any sign of a splice failure observed. Evidently, a splice in the web is not subjected to a very severe strain. Results for Nos. 23 and 24 showed that cover-plates were unnecessary. Nos. 28 to 30 compared slopes of 1 in 7, 1 in 10, and 1 in 13. Although no glue failure occurred in any splice, type No. 28 having a slope of 1 in 7 was not quite so efficient as types Nos. 29 and 30, the ratios being 94, 99, and 101 per cent respectively. Here, too, the splice with a slope of 1 in 10 seems to develop the full strength of the section.

Drawings Nos. 31 to 35 illustrate five types of splice in box beams. Tests of the first two showed, as would be expected, that a splice in the tension flange was less efficient, or at least not more efficient, than one in the compression flange. For this reason the beams were placed with the splices on the tension side in the other tests. Also, as in the case of the three-piece I-beams, the type B splice was adopted and cover-plates were abandoned. Nos. 33 to 35 were then tested to determine the best slope for a type B splice in the tension flange without cover-plates or other reinforcement. The efficiency ratios obtained for slopes of 1 in 7, 1 in 10 and 1 in 13 were 77.6, 92.6, and 104.5 per cent respectively. Evidently, the slope required in such a splice to develop the full strength of the section is between 1 in 10 and 1 in 13.

Summary of Results

(1) Of the four different kinds of scarf tested, the plain sloped scarf is the best, both from the standpoint of efficiency and of ease of manufacture
(2) For such a splice the following conclusions are reached: (*a*) In solid beams and parts of built-up beams in which the height is less than the width, as, for example, the flanges of three-piece I- and box-beams, the plane of the scarf should be perpendicular to the plane of bending; that is, the scarf should be diagonally across the side. (*b*) In beams or parts of beams in which the height is greater than the width, including practically all solid wing beams, two-piece laminated beams, and webs of three-piece I-beams, the plane of the scarf should be vertical; that is, the scarf should be diagonally across the top. (*c*) In beams with the height equal to the width either type of splice can be used
(3) For such splices in Sitka spruce beams with high-grade glue and good gluing, the tests show that a slope of 1 in 10 is sufficient to develop practically the full strength of the section. The average efficiency obtained for this splice in one-piece beams having a rectangular cross-section of 1⅝ x 2¾ in. without reinforcement of any kind, was about 91 per cent
(4) Roughening the scarf does not increase the efficiency of a splice
(5) Dowels or bolts do not materially affect the efficiency of a well-made splice; they do not come into action to any extent until the glue fails. If this occurs in the splice in a one-piece beam, dowels or bolts ordinarily will not prevent an immediate collapse of the beam, unless the joint is subjected to a moment less than 20 per cent of the maximum moment which the unspliced beam will withstand. In the two-piece laminated beam, however, with a splice in one lamination, dowels or bolts may keep up the strength enough to prevent collapse if the moment at the joint is not more than about 65 per cent of the maximum moment which the unspliced beam will withstand. Although results of tests are slightly better for splices with bolts than for those with dowels, the latter are, as a rule, preferable in practice

America as a World Power

By John Paul Goode[1]

Chicago Meeting Address

In President Washington's farewell address of September, 1796, the fear of entangling alliances was written indelibly into our foreign policy. Quoting from this memorable document:

> Against the wiles of foreign influence I conjure you to believe me, fellow-citizens, the jealousy of a free people ought to be constantly awake. History and experience prove that foreign influence is one of the most baneful foes of republican government. The great rule of conduct for us in regard to foreign nations is, in extending our commercial relations, to have with them as little political connection as possible.

The wisdom of this solemn counsel has been conceded by all our statesmen down to the recent emergency. Washington saw clearly our weakness and our isolation, for we were small and poor 124 years ago.

Let us see how small and poor we were and what has happened since that time. In 1800 we had a population of 5⅓ million. We were a small nation. Russia, the greatest nation, had a population of 37,000,000; France, 27,000,000; Germany, 25,000,000; Austria-Hungary, 24,000,000; Italy, 18,000,000; Great Britain, 16,000,000; and Spain, 11,000,000. With only 5⅓ million we were on a par with Norway, Sweden and Portugal. We were a long way off; it required 30 days to cross the ocean 100 years ago. This population of ours was scattered along the Atlantic coast for 1000 miles; we had only penetrated the Appalachian barrier slightly in three places. We were small and weak and poor, and Washington was very wise in advising us as he did. The country's area then was only a little over 800,000 sq. miles. We nearly doubled it in 1803 by the Louisiana Purchase. We have added more land since then until, when the war came, we had an area of 3,027,000 sq. miles and had become one of the world's great nations measured in area occupied.

We have grown in many other ways. Starting with 5⅓ million, we crossed the 100,000,000 mark in 1914. Only one of the great nations could compare with us in the rate of growth; Russia in Europe had 133,000,000 people in 1910. Of the other great nations of 100 years ago, France never reached a population of 40,000,000 until since the armistice. The United Kingdom has grown commendably; so has Germany, but not to compare with us. We have come to be one of the world's great nations, and yet we are still on the Atlantic margin of our continent. The western half of our country is still largely unoccupied. We still are facing the East across the narrow sea, and for good reasons. Comparing ourselves with the rest of the world in population, China has something over 400,000,000; India, 320,000,000; and Russia as it was in 1914, 207,000,000. We are fourth in the world in population, which runs now to over 110,000,000. We are not in the class of Norway, Sweden and Portugal now.

Shipbuilding and Foreign Commerce

In several other ways we have grown great. One of the best ways of measuring international importance today is to consider foreign commerce. The great nations trade across the seas, so we may look at the growth of our merchant marine as part of our study. We had less than 1,000,000 tons of shipping in 1800, and grew very slowly for three decades. Then we increased very commendably and reached a peak of over 5,000,000 tons in 1855. The Civil War reduced that, but we had grown to something like 8,000,000 tons when the war began. In all this century Great Britain has stood high, with twice the tonnage we had in 1800, and had risen until, just before the war began, she had 22,000,000 tons of merchant shipping on the sea. Only once in the century was Great Britain's proud place challenged, and that was between 1855 and 1860 when we ran ahead and stood first on all the seas, with our flag in every port. Our curve has flattened out and in 1914 we came just on a par with rising Germany.

In the second quarter of 1917 we who were watching the destruction of our merchant marine saw that with that rate of destruction of merchant marine, Great Britain could not last six months and there would be a German victory. That was the time and the reason we came into the war. Something happened after we entered it; the destruction dropped off and continued to drop at a very rapid rate until the armistice in November, 1918.

We were not building much in the third quarter of 1916, but we doubled production the next quarter and went right on up until, in the third quarter of 1917, we were building ships to equal the total destruction of ships by the hazard of war, although we had not fairly begun. Our shipbuilding speed had started, however, due to the great shipbuilding yards that were brought into existence as if by magic. A view of the Hog Island shipbuilding yard in 1918 shows 92 keels laid and many ships in various stages of completion. Last year we had an annual shipbuilding rate of more than 4,000,000 tons. We have dropped half of that now, but we have shown our speed and we did the thing that was necessary to do; we built ships.

We have grown in another way as is shown by the record of the increase of total foreign trade. The total value of exports and imports shows that we did not have very much business in 1800. We were very slow in the increase, but by 1860 the curve had begun to rise. The Civil War gave us a setback. By 1910 we found our normal rate of increase in foreign trade and in 1914 our trade was over $5,000,000,000. Then the war began and we went at once up to $9,000,000,000 of foreign trade.

Compare this trade with that of our neighbors. Great Britain was ahead from 1870 on, with a total foreign trade more than twice as large as ours, and with a very rapid increase until, just before the war began, it had risen to about $6,500,000,000. Germany had a trade of about half that of Great Britain at the beginning of this period and it was rising faster. Before 1917 she would have crossed the British curve and have been the greatest commercial nation on earth, if she had not started the war. Last year our total foreign trade went to something like $14,000,000,000, the greatest foreign trade on earth.

There are several other ways in which our interest in

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the outside world has been shown. In the period from 1870 on, it will be instructive to study the source and destination of the items making up our foreign commerce. Great Britain was first in the ranks of the buyers, rising to $600,000,000 at the time the war began. Then Great Britain bought to the extent of $2,000,000,000. Germany was our next buyer, rising very commendably until the war started. France, when the war commenced, reached $1,000,000,000 in the year. The relations we have held with these leading nations are very significant.

A study of the leading five articles of import and export in the same period shows some interesting facts. The leading article purchased throughout all this period was sugar. It ran to $100,000,000 for the whole period until the war began and then it promptly went to $200,000,000. We were buying silk, wool, hides and India rubber, raw materials of large promise which we manufacture into commodities of very high value for our own use or to sell to the outside world. Of the things we were selling in this same period, first for the entire time, is raw cotton, starting at $200,000,000 and rising to $600,000,000 in the year. Close to and sometimes ahead of it were breadstuffs with $200,000,000, then $300,000,000, and then following a crooked curve. If we have a bumper crop we can export a large demand; if we are short at home, exports are less. So the record runs, but all the time we have had $200,000,000 a year to spare, with meat and dairy products rising very rapidly. Before the war began, we had been winning an outside market in iron and steel and copper. When the war began, these foodstuffs, cotton, iron, steel and copper, went to very high figures because they are the fundamental articles out of which world war is made. Without them no nation can function in the making of world war, and we supplied in large measure the exports of the world in those lines.

We can see in another way how our position in the world has changed in 100 years. In a homolographic map of the world, interrupted to indicate ocean unities, the flow of ocean commerce is denoted by bands of color, the widths of which are proportional to the magnitude of the flow of ocean commerce. The world's greatest commercial highway is plainly shown to be across the North Atlantic between the ports of western Europe and our northeastern ports, chiefly New York City; there is no other highway on earth to compare with it. The lines across the Pacific are very slender. This calls attention to another fact, that no nation can buy very much more than it sells, and we are buying enough and selling enough to make our end of this highway. That means that the eastern part of our country is producing enough to sell to western Europe to enable us to buy back from western Europe the articles that flow over the greatest world's highway.

Growth of National Wealth

With a great continent free and untouched before them, rich beyond the dreams of men, our forefathers settled down to work. They were temperate and hard-working, they saved their earnings, invested them and worked again; and by their so doing we have grown rich. How rich, we do not know; our bankers can hardly realize it. We had such a small amount of wealth in 1800 that it scarcely shows above the zero point. It was slow in increasing, but in the 1910 to 1914 period our total wealth is computed at $250,000,000,000. That is all the wealth we have that can be computed in dollars, lands, mines, buildings, machinery, stock and everything else. In 1914 Great Britain had $90,000,000,000, and the entire British Empire $110,000,000,000, less than half of our wealth. Germany had $80,000,000,000; France, $65,000,000,000; Russia, $40,000,000,000; Japan, $28,000,000,000; Italy, $25,000,000,000; and Austria-Hungary, $25,000,000,000. We had the lion's share of the world's wealth. When the national debt is compared with the national wealth to show what fraction of the latter is cancelled or compromised by debt, the estimate for 1918 gave us only 4.8 per cent of our wealth cancelled. Our debt then was $12,000,000,000. It is now $24,000,000,000, but almost half of that is merely an investment in the hands of our Allies. They are paying interest on it and will pay it back. It is an asset, not a debt; so, if the $24,000,000,000 is put in, the real debt is only one-half that large. One-third of the total wealth of Great Britain in 1918 was cancelled by her debt. It is 55 per cent for Germany now and rising rapidly; it is 50 per cent for France. It was 66⅔ per cent for Russia, the last we heard of Russia. Japan had only 4.6 per cent; Italy has gone to over 70 per cent and Austria-Hungary's debt before it was dismembered ran to 96 per cent. If this estimate were made under the conditions of 1921, our wealth would run to $500,000,000,000 instead of $250,000,000,000; so we have grown wealthy; we have grown great.

The war came in 1914 and our position in the world was put to the test. We discovered that we could not stand aloof; that our splendid isolation was a fiction. What actually opened our eyes and made us see that in a world war it is impossible to be neutral was a recognition of the part we play in the commercial intercourse of the family of nations. That ended our neutrality long before we were willing to acknowledge the fact. Our economic advantage in the control of the major supplies of the world's most fundamental material resources, iron, copper, petroleum, corn, cotton, lumber and the like, was the critical influence. The war had not gone very far before all the belligerents saw that these supplies of ours would turn the balance wherever we placed them. It became a war for the supplies, capital, labor and credits of the neutrals; and we, as a neutral, held half the world's supplies. Of the 1,700,000,000 people in the world, our 110,000,000 as it was at the time was only 6½ per cent, but that percentage was producing almost 50 per cent of the coal and iron, 55 per cent of the copper, and just as soon as the war began 80 per cent of the world's copper, and 66⅔ per cent of the world's petroleum. These four are the fundamental things with which nations make world war and we hold the lion's share of them. We are producing 25 per cent of the silver, 20 per cent of the gold, 40 per cent of the lead, 50 per cent of the zinc, 60 per cent of the aluminum, 25 per cent of the wheat and 75 per cent of the corn. We have 41 per cent of all the hogs in the world in our own territory, and we are producing 66⅔ per cent of all the world's cotton. We have 85 per cent of the world's automobiles and, inside of our own area, there is 36 per cent of all the railroad mileage on earth. That is a record to be proud of. The question is, what shall we do with this wealth and what will it do to us? For this prize Great Britain put a blockade on the seas and for this prize Germany developed the submarine. What the blockade did to the Central Powers is very significant. It stopped one-quarter of their wheat at once. It took away from them every pound of their cotton, almost all of their wool and silk, three-fourths of their flax, all of their jute and rubber and almost all of their copper and tin. Those things are fundamental for a nation at war, and no nation

ithout them in large measure can conduct world war. 'e have a suspicion that Germany was hoarding some ' these things. We know that she could not conduct the ar one week after these supplies were exhausted.

Manpower

Let us see what we, as a world power, brought to the nflict, April 7, 1917. To see this clearly we must ask hat the fundamental requisites are for the making of orld war. They are (*a*) fighting men and many of iem, (*b*) food and clothing for the line and the nation ack of the line, (*c*) munitions, especially guns and mmunition, (*d*) transportation service to the front and or the nation back of the front, and (*e*) a willing support ' the war by the people back of the fighting men. Each ' these five fundamentals is just as essential as any ther. A chain is no stronger than its weakest link. et us run the gamut of these five fundamentals and see ieir significance.

In making this survey I give incontrovertible facts. is not mere boasting to say that we are in possession ' the major part of the significant mineral resources of ie whole world. I will state that fact in its details for purpose. The ownership of great wealth carries with great obligations. Merely to boast of our great wealth id power and to use them to take advantage of our eighbors is merely to take on the role of discredited ermany, and to win, and to deserve, the hatred and ntempt of all the world. But to be aware of our power id to use it wisely, will make us the greatest bene-actors of all the ages.

Let us see, then, what we have in the way of great ndamentals; first, in the matter of fighting men. There as a German rule, which we knew very well before 1914, the effect that in the populations of the West one-tenth ' the total population could be counted on for the fight-g units. On that basis we could have had 10,000,000 en in service, but we had 4,000,000 under arms before e had been at it two years. We had virile, educated, lf-respecting men.

Let us notice how the nations taxed themselves in solv-g this great war problem. France had 18.7 per cent f all her men, women and children in her army. That a large proportion. More than one-half of all the men nlisted are recorded as killed or casualties. Germany ad 16 per cent plus, just one-half killed and casualties. ollowing down the list, Canada had 12.5 per cent of all er men, women and children serving in the army; ritain, without India, 12.1 per cent. Next come Monte-egro and Roumania, Turkey, Bulgaria, Greece; and ien the United States with 4 per cent. The sizes of the rmies raised make a better showing for us. The largest ghting unit was raised by Russia, 12,000,000 men and *omen.* Russia held a battle front of 1125 miles and by olding that front for two years made it possible for rance to hold the Hun and for us to have a chance. We ave forgotten that. Look at the record and see the huge oss in deaths and casualties which came to Russia. Ger-iany had 11,000,000 under arms. France had 7,500,000. he British Empire had 6,500,000. We had 4,250,000. f we had taxed ourselves as Canada did, we would have ad 15,000,000 in service or, if we had sacrificed as rance did, we would have had 22,000,000 men under rms; and we would be mourning the death of 3,600,000 oung men.

Food and Clothing

Food and clothing for the nation and for the army onstitute the next requisite. We are better fed than any other people. The average daily ration of the average working man consists of starch, sugar, fats and proteins, four fundamental foods. The proteins are lean meat, peas and beans, or any nitrogenous foods. The food of an army is figured in calories or energy units. The average daily ration is 1140 calories of starch, 600 of sugar, 900 of fats and 360 of proteins. Then come minerals, salts and vitamines. We know that any nation or army going into the struggle must provide these four fundamental foods in proper proportion; otherwise disaster comes. Germany almost lost on account of the lack of fats; she had enough of everything else.

Looking into our cereal supply, we find that we are the largest producer of wheat on earth with an average production that is 791,000,000 bu. larger than that of Russia, which comes next. Wheat provides a good-sized fraction of our starch. Studying the record of our wheat output since 1867 year by year, we find that it is rising splendidly. Some years show a bumper crop and some years are short. In 1915 we produced 1,000,000,000 bu. All the time from 1867 to date we have had wheat to spare, but we passed the peak of our export record about 1890; at the time the war broke out we were on the downgrade. James J. Hill told us before the war began that by the year 1920 we would export no wheat, and that the day we quit exporting we would begin to import. We have had wheat enough uptodate and some to spare. In addition to wheat, we are producing three-fourths of all the corn in the world. It is a perfectly wholesome food but we eat only a small fraction of it. We feed one-third to the hogs and more than that to the cattle. Nevertheless we produce the starch.

The record from 1867 on shows the corn figures going up to over 3,000,000,000 bu. in the year. Oats come up to 1,500,000,000 bu. Then we have, of course, wheat, barley, rye and rice. When we compare our population curve with one of all cereal production, we can see at a glance that the production of cereals is barely keeping up with the increase of population. In addition to the cereals we are producing a large percentage of our starch in potatoes. Our 67,000,000 bu. of potatoes looks small when compared with the 1,600,000,000 bu. of Germany or the 1,000,000,000 bu. of Russia. Our starch supply, uptodate, has been adequate, but when we come to sugar, our record is not so good.

Louisiana produces about 250,000 tons of cane sugar. Colorado is producing just about as much beet sugar. Then we take 617,000 tons from Hawaii, 500,000 tons from Porto Rico and about 333,000 tons from the Philippines. We eat all that and call for more. Next we take almost all of Cuba's supply. We have sugar enough, provided there is peace on the seas; but if war comes we will go short on sugar and pay a fancy price again. Our appetite for sugar has grown. According to the population curve in 1880, there was one unit of sugar to each mouth; but in 1914 there were two units to each mouth. We were eating twice as much sugar and we were not producing very much. Yet, out of the importation and the production, we have had a little to spare. When Europe called on us in time of war, we had a considerable quantity to spare. We are fairly well off in sugar.

In the matter of meats we find that we are not so well off. The curves for swine, sheep and cattle running from 1867 to 1917 are flattening out, and are not at all in keeping with the rise of the population. That is one of the reasons for the high price of meat. We cannot count on sheep very much for food; we are raising most of our

sheep for wool. When we come to hogs, we have 67,000,000 animals. Compare that with Germany and Russia and the rest of the world. Our supremacy is plain. Remember that the hog is the best machine for transforming cheap and common food into high-class human food. The hog, by eating the common food, gives us ham and bacon, that is protein, largely. The hog gives us fat, and fat is the most important thing. Out of our hog supply alone, we can almost furnish our fat supply; so, by supplying proteins and fats the hog is a splendid resource. It is an annual crop also. On the map it is plain to see that there is a hog belt which coincides exactly with the corn belt, for obvious reasons.

A study of the oil supply could not have been made until after the war began. It took the threat of a shortage of oils to arrest the attention of the world and get the data together. Our Government assembled the data. We were producing 1,300,700,000 lb. of butter and eating it all. Then we had tallow and packers' grease and oleo stock and garbage. A surprising thing is that we are producing at the same time almost exactly as much cottonseed oil as butter and the former goes mostly into the food as a substitute for butter and lard. Cottonseed oil is a wholesome, perfectly agreeable human food and we have it in large measure. The linseed oil is not a food. Cocoanut oil is a food and the hope of the world is largely in the cocoanut. Out of our total oil supply, we can spare for other nations 1,000,000,000 lb. each year. We are safe on the oil supply uptodate.

We are well favored in the matter of clothes. When we remember that the great majority of the people are clothed in cotton most of the time, we appreciate what an advantage we have. Smokeless powder calls for cotton. Without cotton there could be no war. If the other countries want war, they must buy our cotton. We have it to sell or to withhold from selling. The cotton is produced in a small area in the southeastern part of the Country. If our agriculture were as intensive as that of the Japanese and Chinese, we could produce all the world's cotton in that area for an endless time to come. But we are losing ground in the matter of cotton supremacy.

When it comes to wool we are not so well favored. We have two areas of concentration of sheep. One in the East Central States is largely for meat, but also for wool; the one in the West is largely for wool. When we see all those sheep we think we have wool enough, but we have not. We were producing in 1914 only 256,000,000 lb. of wool and importing 325,000,000 lb. for our own use. We have no wool to spare. Great Britain produces less than one-sixth of the wool she uses; France is worse off and Germany still worse off. We cannot go without tomorrow's bread but we can go without wool for a long time.

The increase in textile manufactures from 1850 on makes a splendid showing, coming up to more than $1,000,000,000 worth of cotton manufactures, $500,000,000 of wool and $250,000,000 of silk. We produce no silk. We are the largest buyers, the largest manufacturers and almost the largest users of silk on earth. This is merely evidence of what we are doing with our opportunities and what place in the world we are going to hold soon. The clothing item is most important in time of war. An essential part of it is leather. Nearly one-half of our leather supply goes into the making of shoes and boots. The total value of our leather manufactures is $1,000,000,000. We have begun to export boots and shoes tremendously. A good sized fraction of the boots and shoes worn outside the United States comes from our Country.

Munitions Materials

We have little to say for ourselves regarding munitions but we possess the fundamentals out of which they are made. Coal is the most significant fundamental resource of this or any country, so far as industry and commerce are concerned. Of all the known coal in the world, of which there are 7⅓ trillion tons that can be mined under present circumstances, we have over one-half, or 4 trillion tons in our own area. The next largest owner of coal is Canada, with 1¼ trillion tons. China comes next with a trillion tons. Far below China, for China has more than all Europe, comes Germany with a pitiful 0.4 trillion tons, and then comes Great Britain with less than half of that. Before the war began we had an output of 575,000,000 tons; Britain 322,000,000 tons; and Germany 282,000,000 tons. It is evident how small the rest of the world is in the matter of coal consumption and production. There are just four nations on earth that can make or prevent world war. They are the United States of America, Great Britain, Germany and China. Two of them can in fact make world war, and our Nation is one of them. Our record from 1850 on in the great fundamental of coal production is very significant. The production curve starts close to zero in 1850 and grows to an output of 650,000,000 tons for one year. Great Britain at the same time is falling behind. Germany was increasing faster than England and promising to parallel the British output; but she was still far behind us. It is the same with iron. We started at about zero in 1850 and have risen to 39,000,000 tons. The best Germany did was somewhat less than 20,000,000 tons; Great Britain produced slightly less than 10,000,000 tons; and France mined about one-half of that amount. We have the coal and the iron. We have also the lion's share in larger measure of copper. Copper goes into the making of shells and into the making of wires for electrical machinery. Without it there can be no world war. If other nations want copper they must come to us. We are producing 80 per cent of the world's copper.

We have the major share of the world's petroleum also, as an energy asset. It seems that all we need to do in Texas is to bore a hole in the sand and oil sprouts up ready to be piped, refined into gasoline and sold the world over. So we have the chance to supply the world with its liquid fuel in large measure. The next largest producer is the Baku region in Russia and then comes Mexico. The production of the rest of the world is very small. We have produced about two-thirds of the world's output from the beginning in 1875, and which has risen rapidly to 500,000,000 bbl. per year. The curve of Mexico has crossed the 100,000,000-bbl. mark and is going on up. Do not forget that this was a war of motor vehicles. Without gasoline we could have no motor trucks, flying machines or submarines.

In the matter of munitions we began to manufacture small arms for the Allies as soon as the war began, and we were at it for two years. We commenced at once to make big guns; the only big guns we had that got into service came from the battleships. The longest range of the ordinary gun when the war began was 15 miles. We made a gun that has a range of 39 miles. It reached France but did not get into service. However, we did have men and money and food and raw materials, the things which our Allies in Europe wanted so sorely. We

(*Concluded on page* 150)

Cushioning in Motor-Truck Design

By Charles O. Guernsey[1]

Mid-West Section Paper

Illustrated with Photographs and Drawings

MODERN high-quality motor trucks are being designed with the idea of rendering the maximum of satisfactory service in the hands of the user. The more progressive motor-truck builders realize that a permanent business can be built only upon quality as a foundation. The maintenance cost is so much more than the first cost, even with a first-class vehicle, that quality must be paramount. A high-quality 2½-ton truck, for instance, will cost between $25,000 and $40,000 for operation over a life of 100,000 miles, depending upon the design of the vehicle and the service for which it is being used. Obviously, it is poor economy for the user to purchase a truck which will cost an excessive amount for upkeep after a few months of service and which never can render more than perhaps 30,000 miles of service. Truck users are awakening to the fact that a few hundred dollars added to the initial cost of a vehicle may save thousands in the cost of operation.

As a result of these conditions the majority of the reputable truck builders are at this time attempting to supply a high-quality product, which will operate over a period of years with the minimum of maintenance expense. To this end, provision is made for easy adjustment or cheap replacement of worn parts throughout the chassis. This is shown by the use of adjustable bearings in the engine, the wheels and the transmission, and at the differential; and by the use of inexpensive removable bushings at the points of less wear, such as brake-shafts, spring-eyes and steering connections. It is obvious that much thought has been given to this phase of the maintenance problem. However, many designers lose sight of the effect of shocks and strains, which is of even greater importance. A truck is scrapped for some one or a combination of the following reasons:

(1) Obsolescence of design
(2) Wear on vital parts which cannot be replaced economically
(3) Failure of parts, due to shock loads, fatigue or crystallization

In these days of changing fuel conditions and rapid development along all lines, obsolescence of design is of some importance. However, it certainly is not responsible for more than 10 per cent of the casualties among old trucks. As previously outlined, all high-class builders are safeguarding against wear on vital parts to a greater or lesser degree. The failures from this cause are, of course, largely in the hands of the operator, since proper lubrication, adjustment and inspection are essential in reducing them to a minimum. However, the important factors in truck life which are being overlooked are covered under failure of parts. Metal parts of all kinds undergo a change in structure when in severe use, resulting sooner or later in the failure of vital parts such as crankshafts and connecting-rods; clutch, propeller, transmission and axle drive-shafts; and frame members. In addition, there is a great amount of excess wear in bearings and other vital parts throughout the chassis, due to shock loads. The percentage of failures and wear in all of these parts can be reduced very materially by properly cushioning the truck to eliminate the brunt of shocks and strains arising in its use.

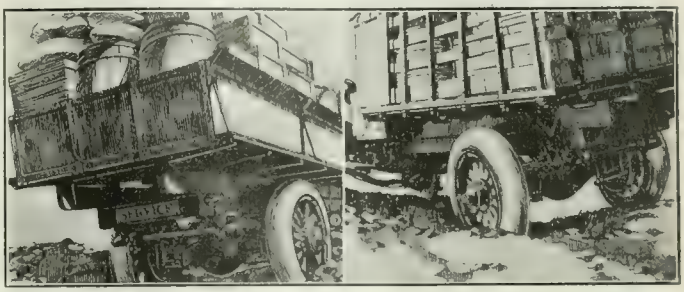

Fig. 1—The Stresses Due to the Load (at the Left) and the Twisting Strains Due to Irregularities in the Road (at the Right)

Chassis Stresses

The stresses and strains set up in a motor-truck chassis can all be classified under one or more of the following headings:

(1) Stresses due to the load
(2) Twisting strains due to road inequalities
(3) Shocks caused by rough roads
(4) Driving shocks and loads
(5) Braking shocks and loads

All the load-carrying parts such as the frame, springs, body, axles and tires, are affected by load stresses. While there are some shock loads arising from this source, due to pitching from side to side, in general the stresses are more or less of a static nature, as indicated at the left in Fig. 1. The stresses covered under the heading of road inequalities are of a twisting nature, caused by diagonally opposite wheels dropping into low places in the road. With the conventional construction, this unevenness of roadway causes weaving or racking of the frame. The springs usually supplied cannot take up all these inequalities. The limit of action for a conventional front spring is about 3 in. and about 5 in. is the limit for the rear spring. The result is that if the frame were perfectly rigid with a conventional suspension, diagonally opposite wheels cannot pass over obstructions more than 4 in. high without tending to lift the other wheels off of the ground. Terrific strains would be set up under these conditions, even if it were possible to make a frame sufficiently stiff for the purpose. Manufacturers generally make the frames flexible, as shown

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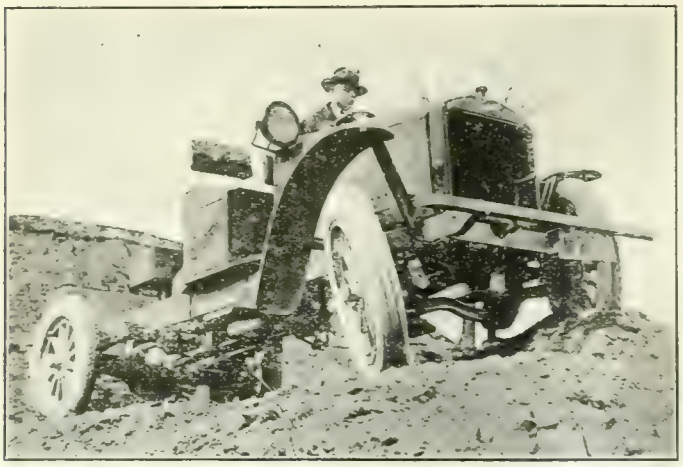

FIG. 2—A SPECIAL SPRING SUSPENSION DESIGNED TO ELIMINATE TWISTING OF THE CHASSIS

at the right in Fig. 1, to permit the road wheels to conform to these road inequalities. In fact, it is practically impossible to make a frame which will be rigid under these conditions. This flexibility, however, has serious drawbacks in causing twisting and weaving in the body, cab and hood, and in throwing parts out of line. This twisting also makes it necessary to use elaborate three-point suspensions on engines and transmissions. If a spring suspension is used which eliminates this twisting tendency, much can be gained. The frame can then very easily be made sufficiently rigid to prevent distortion of bodies, seats and hoods, and misalignment of units.

We have used with very gratifying results a spring construction which puts the entire truck on a three-point suspension. This special spring suspension was developed with the idea of obviating the twisting strains. We used the conventional semi-elliptic springs in the rear with a cross-spring in front, trunnioned up the center, as is shown in Fig. 2. That does away entirely with the twisting of the frame and compensates for the road shocks, strains and twists, in a fairly satisfactory manner. With the left front wheel high and the right front wheel low, as shown, the position of the wheel with respect to the fender and the extreme deformation can be seen, yet the frame is perfectly straight. This illustrates the possibility of designing springs to eliminate the different strains. With a lift of 6 in. on one front wheel and neglecting spring action entirely, the lift on the frame is only 3 in. In addition to this advantage, all distortion of the frame is eliminated by the perfect flexibility of the spring arrangement. A truck so constructed can be driven loaded over cobblestone pavements with remarkably little vibration above the springs.

Fig. 3 is a view of an English chassis, the Palladium, showing a special spring suspension to give better riding qualities than are secured with the ordinary spring suspension. Much can be done along that line. Taking a 1½-ton pneumatic-tired truck as an illustration, the rear-end weight above the springs is about six times the rear-end weight beneath the springs when the truck is loaded. In ordinary passenger-car practice the unsprung weight is about one-fourth of the sprung weight. This indicates that it should be possible to make a 1½-ton truck ride better than a passenger car rides when loaded. When unloaded the ratio is about 3 to 1 as against 4 to 1 in the case of the passenger car; so, even there we should be able to make trucks ride more easily. When we make trucks ride better, the wear-and-tear on the chassis, the load, the road and the driver is reduced.

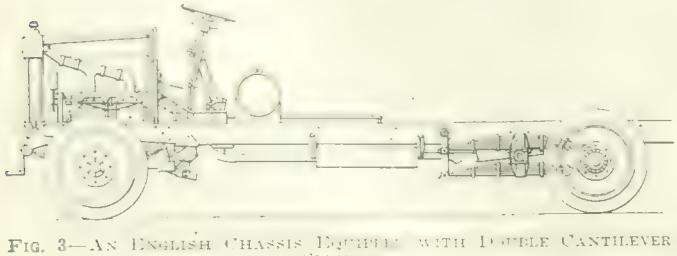

FIG. 3—AN ENGLISH CHASSIS EQUIPPED WITH DOUBLE CANTILEVER SPRINGS

PNEUMATIC-TIRE CUSHIONING

According to our division, rough roads undoubtedly do more damage than any other type of shock. This includes the terrific vibration due to cobblestone pavements and the short, rapid impacts due to sharp holes and bumps in the road, indicated in Fig. 4. These shocks cause vibration throughout the truck which results in the loosening of various bolts and connections, the cracking of soldered joints, the breaking of copper tubing and the crystallization of all sorts of parts. This type of shock if not properly absorbed will cause fatigue sooner or later, regardless of the quality of the steel or the heat-treatment used in its manufacture. These shocks can be reduced largely by careful design of the springs and the use of live or resilient frame-members of wood or pressed steel as opposed to the heavy inert rolled-steel

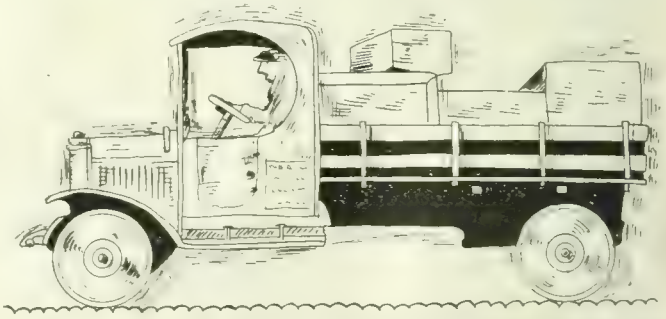

FIG. 4—THE TYPE OF SHOCKS CAUSED BY COBBLESTONES AND CAR TRACKS

type. Naturally, the tires are the most important factor of all. If conditions are such that pneumatic tires can be used satisfactorily, they will in a large measure furnish a solution of the difficulty. Oftentimes, imperfect or badly worn solid tires are used and about the only real good they do is to deaden the noise. The impact forces vary according to load, speed, spring suspension and the like, but the following statements are true approximately.

It has been shown that a pneumatic tire loaded to rated capacity deflects 11 times as much over an ordinary obstruction as a solid tire which has 1 in. of live rubber; and five times as much as a new solid tire, shown in Fig. 5. These tests were made by putting a load on the spindles of wheels having these respective tires and then measuring the deflection. Under a 7000-lb. load the 36 x 6-in. solid tire deflected 0.7 in., while the 40 x 8-in. pneumatic tire deflected 3.4 in. That gives us a reasonable measure of the relative stresses, other things being equal. The impact force is inversely proportional to the deflection. Even with new solid tires the impact forces are three times as great as with pneumatic tires. This means that a pneumatic-tired truck running at 24 m.p.h. will not set up any greater stresses than a truck with new

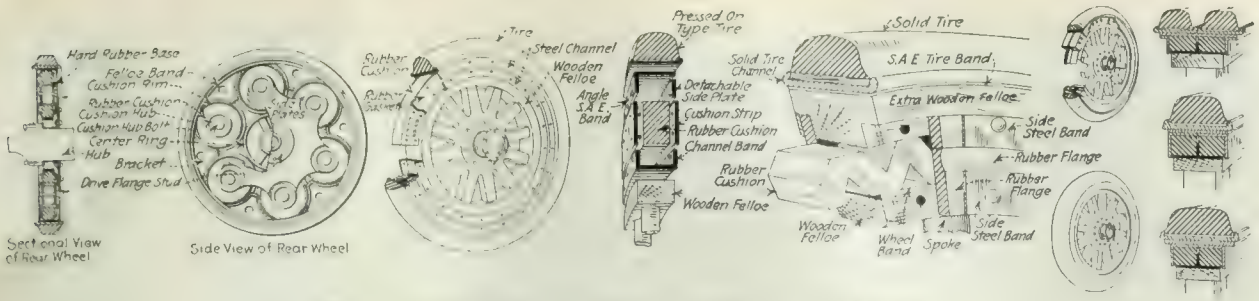

FIG. 6—VARIOUS TYPES OF CUSHION WHEEL IN COMMON USE

solid tires running at 8 m.p.h. The impact forces with pneumatic tires rarely exceed the static loads by more than 50 per cent. With solid tires the impact forces may in extreme cases run to 1000 per cent of the normal load. Pneumatic tires, if they prove satisfactory from other standpoints, will contribute largely to the reduction of stresses due to road impact. We must remember also that excessive wear-and-tear on the highways will cause opposition to the use of trucks. We must design trucks so that they will cause the least possible damage to the roads over which they travel. The truck which can accommodate itself best to the road will, in turn, cause the least injury to the road. The wear-and-tear on roadway surfaces is largely a matter of impact.

Fig. 5 shows, at the left, a 44 x 10-in. pneumatic tire dropping off of a 2-in. bump and striking with an impact force of only 8000 lb. with a live load of 7000 lb.; at the right is shown the corresponding size of dual solid tire dropping the same distance at the same speed, but having an impact force of 45,000 lb. The impact in this case is more than six times the amount of the live load. That impact affects the wheel bearings, the spindles and all of the unsprung parts just as if they had been hit by a hammer-blow of that amount of force. The pneumatic-tire impact was very little over the rated load. So we must remember that the truck which can conform to road inequalities and absorb shock will at the same time inflict less damage on the road.

These statements may lead to the belief that I am an advocate of pneumatic tires. This is not necessarily the case. While the advantages resulting from their use are of great importance, we must realize that there are disadvantages which must be considered fully. For some applications they are proving ideal; on others they are not suitable. On the large heavy-duty trucks, for instance, they are at this time practically out of the question. It is these trucks which suffer most from impact and in turn inflict the greatest damage on the roadway.

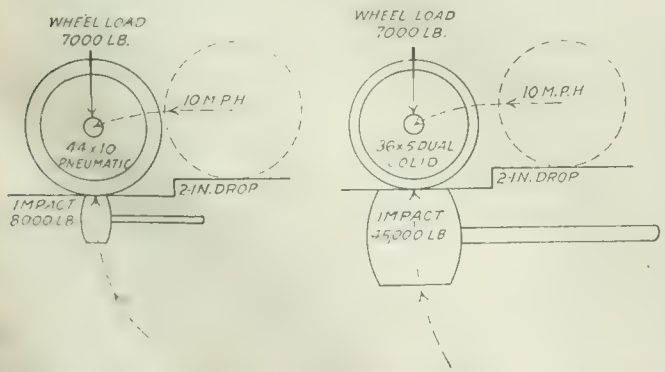

FIG. 5—A COMPARISON OF THE IMPACTS PRODUCED BY PNEUMATIC AND SOLID TIRES FALLING THROUGH THE SAME HEIGHT

For the present, we are forced to look elsewhere for a means of cushioning heavy trucks against rod shocks.

CUSHION TIRES AND WHEELS

As a result of efforts along this line, we have several types of cushion tire which hold considerable promise. The cushion wheel has proved its worth, although many of these wheels add so much to the unsprung weight that the advantages are offset to a great extent. Fig. 6 shows types of cushion wheel. To illustrate some of the possibilities of cushion wheels and of increased cushioning of any kind, in the case of an electric chassis which was originally equipped with solid tires and standard wood wheels, it was possible to get a speed of 9 m.p.h. in ordinary service. Another vehicle, an exact duplicate, equipped with caterpillar tires and the cushion wheels, was attaining 14 m.p.h. over the same route under the same conditions. After trying a number of different expedients, the users switched the cushion wheels and tires and obtained the 14 m.p.h. on the other vehicle; the increased cushioning had decreased the rolling resistance so that the electric motor was able to propel the vehicle at a higher speed.

Much wear-and-tear can be saved on trucks equipped with solid tires by promptly discarding a solid tire which has worn down to within 1 in. of the hard-rubber base. A recent inquiry among a number of large users, such as the Standard Oil Co., American Railway Express Co., Wanamaker's, Marshall Field & Co. and The Fair Store, showed that this is general practice with fleet owners. The use of a badly worn or defective tire can do damage to the truck in a few miles of running amounting to the price of a new tire. The tire companies can be of great service to the industry by adjusting solid tires on the basis of 1 in. of rubber in a worn-out tire. As it is, many of them insist that a tire is not subject to an adjustment as long as there is any sign of live rubber on the base.

The realization of the advantages and shortcomings of pneumatic tires is leading to a considerable demand for a tire which will to some extent at least combine the advantages of solid and pneumatic tires. The result is a considerable interest in various types. These tires combine to a lesser degree the cushioning, speed, and traction possibilities of the giant pneumatic tire with the low cost and dependability of solid tires. Fig. 7 shows various types of cushion tire. The use of resilient frame-members, improvement in spring suspension and in tires and better design in other ways, will greatly reduce the damage resulting from road vibrations. Certainly this phase of the problem merits our best consideration.

The solution of the problem lies not so much in the elimination of shock as in reducing its intensity, by distributing the force of impact over a greater length of time. If a man jumps out of a fourth story window to

Fig. 7—Different Cushion Tires for Use on Trucks

the pavement, he is killed or seriously injured; but if he jumps into a life net he is not harmed. The force is the same in both cases, but the impact is distributed over a greater length of time when the man lands in the net. Means must be employed to distribute the force of impact in a truck over a greater time in a similar manner, thus reducing its intensity.

Fig. 8 portrays the driving shocks. A tremendous load is put upon the parts when the engine is applying its power through the transmission, the rear axle and the different gears and shafts along the line. When running along under ordinary conditions the strains are not so severe, but when the wheel spins and then suddenly takes hold, it causes a tremendous shock all through the parts. If the brunt of the shock can be eliminated in some way, for instance, when the clutch is suddenly dropped in or in a case where the wheel is spinning and then suddenly takes hold, the stresses in these parts can probably be cut down at least 50 per cent. There are a number of ways of doing this and on many different trucks various methods are employed along that line; for instance, the Hotchkiss drive, in permitting a certain displacement of the axle, helps to a great extent in dissipating or cutting down the amount of those shock loads. This is illustrated in Fig. 9. Whether these blows have the effect of a hard steel hammer or of a soft rubber hammer depends upon the absence or provision of cushioning factors. Parts in a properly designed vehicle are not broken by the steady torque or weight load. It is the exceptional shock load which causes stresses beyond a safe limit and finally causes failure. Still another type of shock, the braking load, is simply the reverse of driving or torque shocks, as indicated in Fig. 10. Various parts are affected according to the design of the brakes and depending also upon the engagement or disengagement of the clutch when the brakes are applied.

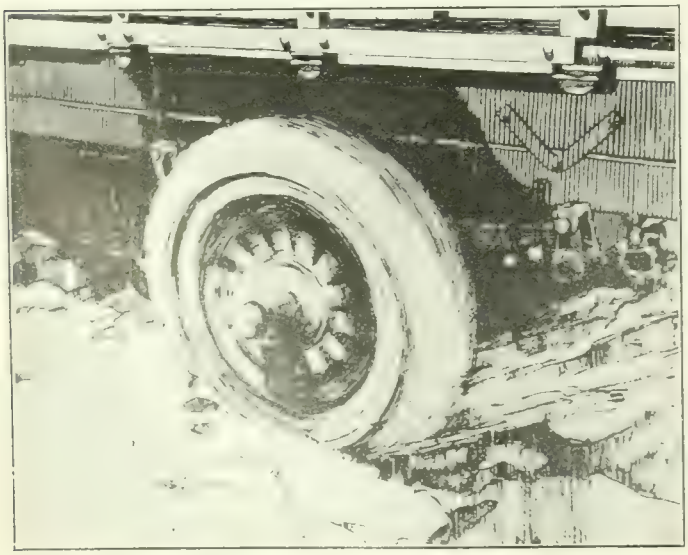

Fig. 8—Stresses Exerted by a Truck

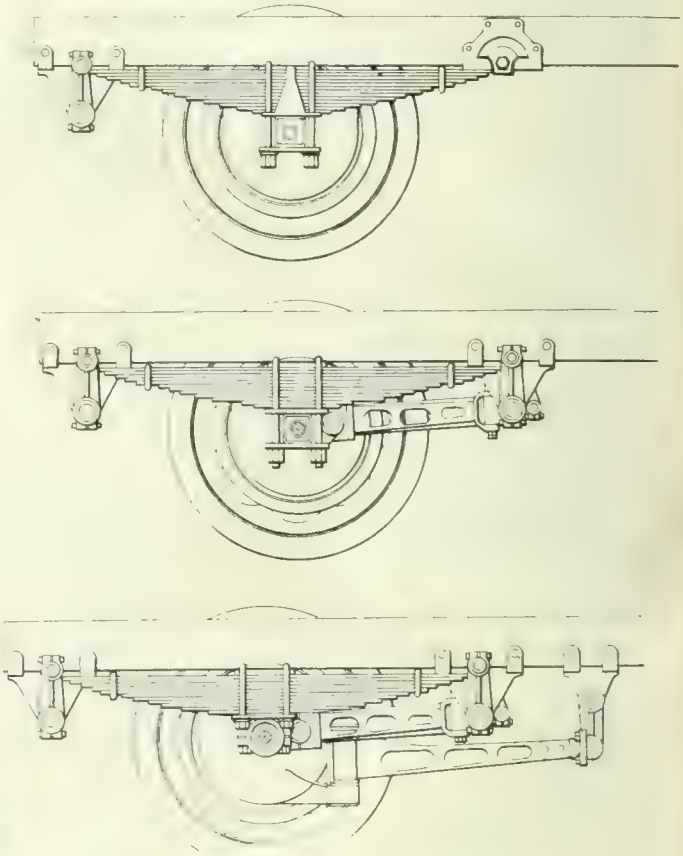

Fig. 9—Constructions Developed to Reduce the Shock Load to Which a Truck Is Subjected

Elimination of Vibration

Vibration, caused by shocks of the varied kinds, is the most destructive factor which must be overcome in motor-truck design. The designer who succeeds in reducing shock or vibration stresses can make a lighter vehicle and also a more satisfactory product than possibly can result from heavy inflexible design, assuming of course an equal standard of engineering in other respects. A sportsman would never think of using a fly-casting rod which was as stiff as a broom handle. He would be certain to break his line. Instead, he uses a light pliant

rod which smooths out the load on the line so that there is no danger of breakage. There are already many features of design which help to some extent in achieving this point. Great improvements should be expected in spring suspension. We have made brief mention of one special spring suspension which has shown good results. We should not overlook the possibilities of a suspension having a graduated deflection. This can be achieved by using light springs, together with auxiliaries of some sort which come into action under extreme deflections or loads. We have been too prone to accept the conventional in this regard. A line of practical investigation along this line, conducted by a practical engineering staff, should show some remarkable results. Another feature which is of considerable value is the use of pressed steel or other shock-absorbing material for frames.

The circumferential displacement of the tires, of course, helps to some extent. The use of flexible-fabric universal-joints is of material help in that connection. Graflex pictures showing flexible-fabric universal-joints in service, taken when operating on low gear, show that they do deflect a very appreciable amount under certain conditions, and thus smooth out the torque curve between the engine and the rear axle. In this way wear and breakage are reduced in all torque-transmitting parts. These joints do for the driving line what the cushion does for the driver. Several years ago a chain-driven truck kept breaking jackshaft bevel pinions continually. An investigation showed that this breakage resulted from shock caused by a fierce clutch and by the slack in the driving chains. The use of a fabric universal-joint cured the trouble.

Engine vibration can be reduced materially by proper mounting. The engine should be anchored in such a way that it cannot possibly vibrate in its mounting. It is perfectly possible to mount an engine so that slack, with consequent vibration, cannot develop during the life of the truck. For instance, the use of a stiff spring on the engine-support bolts and on the trunnion bearing cap at the front point of suspension in the case of a three-point mounting, will hold the engine tightly in place and still permit the usual weaving and twisting as required with a conventional spring suspension.

A truck when properly cushioned will have less wear-and-tear and less shock breakage and carry its load with the minimum of damage. As a result of shock reduction the chassis can be made lighter. This, in turn, will reduce the amount of power required, thus further decreasing stresses. This will lessen tire wear, gasoline consumption and other items of operating and maintenance expense. Another possibility lies in increased speed. I predict that as a result of the use of scientific cushioning in design we will see trucks within a short time which are at once lighter, stronger, more economical because of lighter weight, faster and, in general, more suitable for use than present designs. The truck must conform to the road. It cannot be built so as to resist punishment from the road. It must be capable of receiving, absorbing and nullifying road shocks. It must be properly cushioned.

THE DISCUSSION

B. S. PFEIFFER:—Did Mr. Guernsey use any radius-rods on the front axle with the cross spring?

CHARLES O. GUERNSEY:—We have to do that. We have a three-cornered radius-rod since that is the only thing that can be done successfully.

F. E. BLANCHARD:—One thing that has been causing much damage to motor trucks recently is the lower gear-

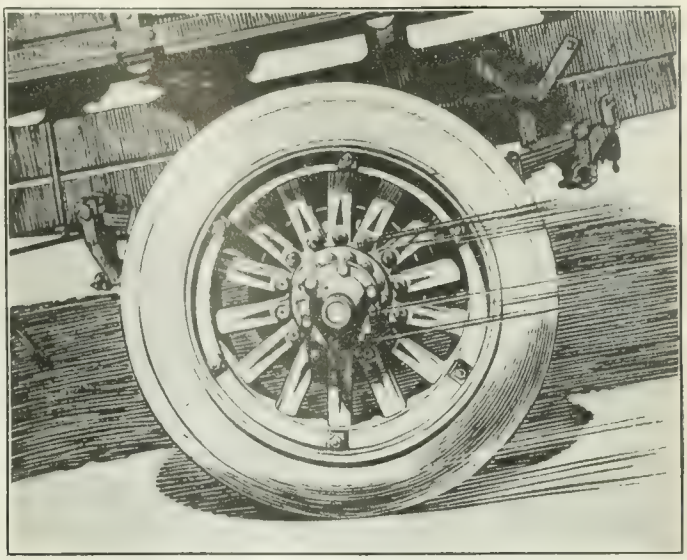

FIG. 10 STRESSES SET UP IN A TRUCK WHEN THE BRAKES ARE APPLIED

ratios used and the higher tractive effort. I have been in a district lately where much damage was being done to all types of truck. It was not done at speed, but under low-gear conditions where truck towing was done with and without tow-hooks. One truck may be down in a hole and another truck pulls the first one out. Instead of properly equalizing the towing chain, the driver generally wraps one end of the chain around one of the side-rails of the truck frame, puts his truck in low gear and proceeds to pull the other truck out of the hole. I have seen in one case a 3½-ton truck pulling two 100,000-lb. freight cars, with a chain wrapped around the left side rail of the truck. I had no means of measuring the deformation of the truck frame, but it went out of square between 1 and 2 in. The driver was rather proud of the effort, instead of realizing what he was doing to the truck frame. To show such things by motion pictures would benefit the trade in general. In similar cases I noticed engine supports and rivets torn loose, transmissions that it was impossible to keep tight, gusset plates torn in two, cross-members broken and many rear-frame cross-members pulled out. There is a great amount of such abuse that should be corrected.

MILTON BECK:—Much good has come to a number of new industries by collective advertising. The cement business was at a very low ebb a few years ago. Then the cement people issued advertising along the lines of what can be done with cement and how to use cement. Perhaps some company's name appeared, but the advertising was largely a building up of the cement business. If the men who do the advertising in the motor-truck business could devise some collective advertising scheme whereby these troubles could be emphasized, it would help the truck business very materially. The truck business really deserves a campaign of education on the use of trucks and how to use them to get the most service.

L. W. PIETSCH:—Knowing that their trucks will be used at some time as a motive power for towing, I believe it behooves the builder to improve the construction of the truck-frame bracing. This would help to eliminate much of the twisting strain which distorts the body and would tend also to eliminate the shocks from the truck wheels to the engine.

MR. GUERNSEY:—We are all hoping that the pneumatic

tire will succeed, because it makes our work much easier, but we are obliged to go according to the evidence. Probably it will win out eventually on 1, 1½ and 2-ton trucks, and possibly on larger ones. There have been some experiments with pneumatic tires on 5 and 6-ton trucks; some of them have proved very successful in an experimental way. I refer particularly to the Goodyear six-wheel truck experiment. The truck rides and performs well on the road. It is possible to use the same size of tire on each wheel, and the same pressure on each. A tetering movement obtained in going over bumps seems to absorb the shocks. I rode on one of these trucks over so rough a brick pavement that an automobile that was going alongside at probably 10 m.p.h. was bounding up and down. We drove down that street at 30 m.p.h. with a 6-ton load. Four of us were sitting in the back of that six-wheel truck; we had no cushion and were perfectly comfortable. That indicates the possibilities of pneumatic tires if they can be made to stand up well enough to keep the repair cost within a reasonable figure.

Until we can get a spring suspension that will take up the road twists and the inequalities, we practically are obliged to use the flexible frame. An ordinary front spring will deflect about 3 in. and an ordinary rear spring will deflect not over 5 in. We have, as I mentioned, built a truck with semi-elliptic springs in the rear and a single cross-spring in front with a trunnion in the center, and we are going to market it that way. It seems to work out very well. We put the engine on a four-point mounting and, for testing purposes, put on a load that was pretty high from the ground. The front end rode well, but when the rear wheels hit a bump it would swing off sidewise. We were able to get around that by making the rear springs long and putting in rebound leaves. The effect we get now is that if one front wheel of the truck goes down in a hole it is scarcely noticeable. Then, when the rear wheel comes along and hits that hole, it just drops off a little bit sidewise. So, we have been able to get a remarkably easily riding truck. The platform spring in the rear is all right, but usually lateral stability is needed in the rear more than in the front, because the rear springs are the stiffer and carry most of the load. If we put a platform spring in the rear and then attempt to maintain the lateral stability from the front springs, we sometimes get into trouble.

Referring again to the Goodyear six-wheel truck, the Department of Agriculture made a test of that truck and found that each of the four rear wheels had about the same impact effect as the rear wheel of a pneumatic-tired 2-ton worm-drive truck with its rated load. In other words, by dividing up the load among four smaller wheels and using smaller tires, not only were better riding qualities secured and the damage to the truck reduced, but the impact force exerted on the road was actually cut to about one-seventh what it would otherwise have been. So, it may be that we can install multiple axles under the rear end of the big 5-ton trucks and divide the load so as to reduce the terrific impact force.

If there is a cushioning factor in any part of the chassis, whether it be in the load-carrying or in the driving parts, which will cut down the shocks and stresses in those parts one-half, the size of those parts could be reduced to a great extent. If we can save weight in the chassis, we can save cost for the operator. By incorporating cushioning features we should be able to make an appreciable reduction in the chassis weight. According to figures showing the operating costs for different sizes, from 1½ to 5-ton trucks, it costs between 4.5 and 10.0 cents per ton of gross weight of load, chassis and body, to move a truck over the road. If we can reduce the weight 1000 lb., we will say, on a 5-ton truck, we can save about 3 cents per mile for the operator.

R. M. GASTON:—In connection with the spring coupling, I know of one particular design of railroad motor-car which was designed with a spring coupling between the engine and transmission. In this position it transmitted only the engine torque and was very successful. It is commended particularly for railroad car use because the cars have no rubber tires and there is a very limited flexibility in the drive. A number of them were built and seemed to be successful. It might not be out of reason to use something of that kind on a truck, especially where solid tires are employed.

MR. GUERNSEY:—The flexible rubber and fabric universal-joint serves much the same purpose. A spring coupling probably would give a greater angular displacement under a certain shock, but the flexible rubber universal-joint minimizes the blow. A spring wheel will not stand up on the road, because it cannot yield to the instantaneous blows. There is too much inertia. We might encounter similar difficulties with a spring coupler, but the rubber will yield to instantaneous blows because, practically, there is no inertia. Rubber might serve the purpose better even than a spring shock-absorber. We tried one of the latter between the propeller-joint and the flange. It weighed about 40 lb. and worked well, but we concluded that it introduced an unnecessary weight.

MR. BLANCHARD:—Are the impact forces you have given taken from actual tests, or are they from empirical data?

MR. GUERNSEY:—They are taken from actual tests.

UNIVERSAL-JOINTS

A MEMBER:—I am informed of a serious trouble with the fabroid joint. Several of the major companies in the East have made extensive tests on it and with the three-point joint, in which two planes travel but not in the same line. The results have shown that a hammer-blow occurs when the shaft is inclined at an angle of 4 deg. or more, which is repeated three times in every revolution. That effect has been very detrimental to several makes of car. One of these companies that produces a light car has had to change the construction in both the transmission and the rear axle due to that trouble. This company will attempt to remedy the difficulty in several different ways, one of which is to reduce the shaft angle, which has been proved to be less than 4 deg., and otherwise to strengthen the construction. One company is installing the fabroid joint between the engine and the transmission, using an entirely separate joint to relieve the engine from the stress shocks and allowing them to come up through the axle, the transmission and the propeller-shaft, and the method has met with success. I believe we are to see a mechanical joint on one of the new cars this year. This difficulty has been found to be a very serious thing to contend with. I do not know whether Mr. Guernsey has had any experience with those high shaft-angles, or whether his experience would corroborate mine. One of the larger companies is working with a joint now which is a true universal-joint. The joint that we have now is more of a flexible coupling. The company to which I refer is working with a prong joint having a thicker disc and has obtained results that so far are very satisfactory. I have taken this question up with some of the engineers of several of the companies that manufacture these joints. They have admitted the

condition, recognize it to be a serious one and have attempted to correct it in several ways. I know of three large companies at present that are considering changing the joint, or the construction or whatever is necessary to get rid of that condition.

MR. GUERNSEY:—When we first began experimenting with the flexible fabric joint we tried it both ahead of and at the rear of the transmission. In our particular line the transmission is about amidships. In the case of some short-wheelbase trucks where this joint was used back of the transmission, we had some difficulty because the angle was too great; but it has been our experience that where the maximum angle obtained under the worst condition does not exceed about 4 deg., the end-thrust or the hammer-blow in an endwise direction is serious enough to cause concern. In fact, the blow, being administered through rubber, is deadened. If there is an extreme angle, it causes a bad condition. It has been our practise to employ the flexible fabric construction between the transmission and the clutch, using the standard metal joint back of the transmission. The shocks are absorbed at some point in the line, so that it makes little difference where it is. If provision is made somewhere in the line to take care of this condition, the case will have been covered. It is not necessary to use flexible fabric joints all through. In the case of a unit powerplant design, we are using a flexible fabric joint on the axle end of the propeller-shaft and a metal joint on the transmission end. An advantage of this arrangement is that, as the axle is displaced in riding the road, an excessive end-thrust is not being put on the bearings; that is accommodated through the slip joint. Where two flexible fabric joints are used between the transmission and axle without the slip joint, as is done by some companies, this is not the case.

A MEMBER:—In experimenting with the flexible joint behind the transmission, do you have any trouble with the bearings in the transmission?

MR. GUERNSEY:—No; we equipped about 50 trucks, built about March, 1915, and I daresay 40 of them are still running with the original shafts.

MR. BLANCHARD:—Was that a straight-line drive?

MR. GUERNSEY:—It was supposed to be straight-line under load, but some of the rear shafts on dump trucks were very short. We did get some extreme angles on them in rebound and with extreme load, and we had trouble with the bolts that carried the discs. They broke off because of the constant bending back and forth.

CONCRETE ROADS

B. B. AYERS:—The concrete road will rule ultimately. There is as yet no material except concrete that will stand up. The construction companies should advocate universal adoption of the concrete road. Without doubt this will be accomplished, and we will begin to see results within about five years.

MR. GUERNSEY:—I am doubtful about that. I have seen some concrete roads that were considered very fine on which the surface was broken down due to the abrasion of passing vehicles. I am inclined to think that we need to put in a good road foundation and then put an asphalt coating on the top to take care of the abrasion. Cushioning in the road is just as logical as cushioning in the vehicle.

MR. AYERS:—Such abrasions are due to poor mixtures. In Wayne County, at Detroit, in five years there has been no abrasion whatever, because the roads were laid with a mixture that was absolutely perfect and carefully supervised. In that time the concrete and gravel wore down evenly and left no holes, because the mixture was homogeneous. Our great trouble will be in obtaining good engineers who will make the proper selection of materials and lay them right.

CHAIRMAN G. I. BRIGGS:—What information have you on California concrete roads?

MR. AYERS:—California has climatic conditions that do not apply in the East. Eastern roads are sometimes subjected to temperatures of from 8 to 40 deg. below zero Fahr. in winter. The fine new concrete roads in Wisconsin are subject to these low temperatures. They must withstand leakage and seepage, freezing and thawing. I think it is marvelous that those roads can be maintained at all under such circumstances. There is not a single devastating element of that nature to contend with in California.

MR. BLANCHARD:—Mention has been made of the road between Detroit and Toledo and how it disintegrated. This road was too narrow in the first place. At the time it was constructed there was a great demand for inter-city transportation. Many Army trucks were being built at Detroit. They traveled from Detroit to Toledo and brought goods back. The Army truck drivers needed plenty of clearance. The result was that they ran over the concrete edge of the road and started breaking down the edge. As soon as that occurred and frost entered the roadbed, the bad spot immediately began to progress toward the center of the road. In some cases there are oval bad spots that have gone in almost to the center of the road. This also has been the cause of many accidents.

A MEMBER:—The conditions under which that road was built were probably as bad as any we have had to contend with. They have bottom conditions there that have been almost impossible for the last 20 years. They should have taken twice the amount of money they did to build that road, and they will be forced to do so eventually. The bids on some roads in Illinois range from $42,000 to $45,000 per mile. Bridges must be constructed that are practically as good as those built for a railroad, or they will not stand up under the heavy trucking service. This will cause contention between the users of passenger cars and the users of trucks.

A MEMBER:—I made several trips last winter and in the early spring over the road between Toledo and Detroit, and know some of its history. One of the construction superintendents told me that it had about a 10-in. base, 8 ft. wide, and that the sides fell off to 6 in. in depth. We made the trip at night several times. At that time they were doing a considerable trucking of engines from Detroit to Toledo using heavy trailers, and there was considerable sway at all times on them. I have wondered whether the truck builders took into consideration the sway and pitch on the trailers. The load on the trailer was as heavy as that on the truck itself. The truck builder should work with the highway engineers and the road builders in that connection.

MR. GUERNSEY:—An attempt is being made along that line at present. The Federal Highway Council is made up of men prominent in the automobile and motor-truck business and leading highway engineers. They have an appropriation for the study of sub-grades, foundations and road surfaces. The idea is to try to arrive at some specification for the proper road to meet certain conditions in the various localities. They consider the drainage of the sub-grade and the matter of seepage, which was mentioned as being the paramount thing. They

assume that there must be a sufficiently heavy foundation and that the proper surface must be determined, but the thing that seems to be making them the most trouble is the question of draining the sub-base.

Liquid Loads

MR. PIETSCH:—Have any experiments been made as to the difference between liquid loads and dead-weight loads carried in trucks and what relative difference there is? My experience with liquid loads indicates for instance, that a 2-ton truck should really be rated as a 2½-ton truck. We have trucks in the service of carrying liquids. Those liquids are swish-swashing around all the time and, in going around corners, the strains are in different angles all at the same time. I believe that at least 50 per cent must be added to the average capacity of a truck if it is to be used for liquid transportation. I suggest that builders of trucks make a note of that point and verify it, which can be done very readily. We have found it necessary to install baffle-plates in the tanks at certain points. I think 300 gal. is about the limit for tanks, regardless of how heavy the walls are built. Baffle-plates are necessary; without them, in going around corners, the truck is likely to turn over. We have used some of our old tanks, but they were all coupled up and baffle-plates put in. People do not realize the enormous amount of pressure there is in such tanks; even the baffle-plates are torn out at times.

Engine Support

MR. BLANCHARD:—In the description of the non-flexible frame with a transverse spring at the front end, Mr. Guernsey mentioned that he changed from a three-point to a four-point engine support to obtain additional stiffness in the frame. Is the engine crankcase relied upon in any way to afford the additional rigidity?

MR. GUERNSEY:—In our construction we have always tried to mount the engine in such a way that it never can get loose and cause damage. An engine that is bolted down to the frame in the ordinary way jumps up and down and hammers things all to pieces. That is one source of vibration which is very detrimental. If it can be eliminated, something very much worthwhile will have been accomplished. In the last four or five years we have made it a practice to mount the engines with a stiff spring holding down the leg of the engine. That serves the dual purpose of permitting a slight flexing and keeping the engine tight on its foundation and preventing up-and-down vibration. When we put the engine on four-point support, it was natural that we should put the usual springs under each of the engine arms. Those springs have a capacity of 300 lb. and I never have seen any one of them rise off its seat; so, I am sure we are not getting any more than 300 lb. of strain on any one of those arms, and it is a pretty poor crankcase that will not withstand that amount.

AMERICA AS A WORLD POWER

(*Concluded from page* 142)

could give these materials to them and they could make the big guns. That was a very fine bargain. We had a navy that functioned well. The record of recent years of the navy growth shows our navy coming up to 1,000,000 tons. The largest navy on earth, that of Great Britain, was a little short of 3,000,000 tons. Germany was next. The war came. When the British, United States, Japanese, Russian, French and Italian navies were combined, Germany had to keep her navy in safe waters.

Transportation

We had no lessons to learn from the outside world when it came to transportation. Because of our network or railroads every farm and every factory in this whole land could get its materials into service without delay. That was exactly what happened. Think how Russia and some of the other Allies were handicapped. The world's growth in railroads shows that the United States, beginning at zero in 1840, has risen to first place as usual; the next greatest nation is Russia; then come Germany and France, Great Britain and Italy. It is not fair to compare our railroad mileage with theirs individually. We ought to compare ours with that of Europe. We could serve and are in a position to serve. One of the Baldwin monster locomotives is typical of our equipment. It consists of two engines combined into one, being equipped with 24 drive-wheels and jointed in the middle so it can go around a curve. Oil is used as fuel and two men run the engine. It will draw more than three times as large a load as the largest ordinary locomotive ever built. Before we had been in France 11 months we had built railroads from Brest and Bordeaux on the west to the mountains on the east, a mileage greater than the entire Erie system.

We learned that war is business, and that back of the fighting men all the industries of the Country must be organized to serve the one purpose of winning the war. Therefore, the leaders in all these lines were called upon. A legion of scientific men came forward to solve problems in mathematics, chemistry, physics, electricity and engineering. Now the problems of peace arise, more difficult to solve than those of war. As owners of nearly one-half the significant mineral resources of the world and almost half of the present wealth of the world, we find ourselves loaded with a great responsibility. May we realize earnestly that the ownership of large wealth carries with it large responsibilities and that those responsibilities cannot be evaded. Let us remember what are the material foundations out of which world war is made, and that there are just four nations that can make or prevent world war. Let us see to it that we have a square deal for three parties at home; first for capital, second for labor and third for *the rest of us*. America is great enough to be just; America is great enough to be generous. May we use our great opportunities and powers wisely, so that, as a world power, we shall deserve the respect and gratitude of all men for all times.

The Need for Federal Control in Commercial Aviation

By S. H. Philbin[1]

Semi-Annual Meeting Paper

COMMERCIAL aviation in the United States is to-day in imperative need of adequate control by Federal legislation. Its situation and necessities will first be outlined and then there will be suggested a plan of legislation which appears to be well suited to meet its present and future requirements. As a preface, it will be helpful to consider briefly certain legal principles applicable to aviation. There are certain fundamental legal principles which will control the courts in deciding the many interesting and complicated problems which will occur in aviation. It is sufficient here to indicate their nature, without attempting to discuss them in detail.

National, State and Private Rights

The right of a nation to control the passage of aircraft over it has sometimes been doubted, but it seems perfectly clear that a nation has the unqualified right to prohibit or license the aircraft of other nations. The exercise of this right will depend upon international considerations of comity and convenience. The United States can forbid the aircraft of other nations from passing over its territory, and this view is now commonly accepted.[2]

Each State of the United States has full power to control and regulate aircraft within its limits, until Congress has exercised its constitutional power "to regulate commerce with foreign nations, and among the several States, and with the Indian tribes."[3] This right of the States is well illustrated by the case of Kane versus State of New Jersey,[4] where a State statute required non-resident owners of motor vehicles to appoint a State official upon whom process could be served and also required the payment of a registration fee, and the statute was sustained by the Supreme Court. These powers of the States cease when Congress speaks.

The question of what is interstate commerce has been before the courts a very great number of times and precedents of great value to air law have been established. To illustrate the length to which the courts have gone in holding that interstate commerce was involved, the recent case of New York Central Railroad Co. versus Porter,[5] held that an employe shoveling snow between tracks used in interstate and intrastate traffic and there killed was engaged in interstate commerce. It seems clear that Congress has jurisdiction to enact legislation covering not only aircraft engaged in flying between States, but also aircraft which, although solely within one State, may interfere with aircraft engaged in interstate or governmental business. The State and the Federal courts would have concurrent jurisdiction over all questions arising out of legislation applicable to aircraft. Any suit arising under such Federal legislation could be brought either in the State court or in the Federal court. If brought in the State court it could be removed to the Federal court.[6]

The two most interesting questions of private rights are (*a*) whether the landowner owns or possesses "usque ad coelum" and has such a right in the air space above the land as to be able to prohibit others from flying above his property; (*b*) whether there is an absolute liability upon the part of owners and operators of aircraft for persons and freight carried; and (*c*) what is the liability of aircraft owners and operators for damage done to private property in landing or falling. It is sufficient for present purposes merely to indicate these questions and to state that the best opinion is that the landowner cannot prohibit aircraft from passing over his land but can restrain them from flying so low or being so noisy as to constitute a nuisance. The same well considered opinion is also to the effect that while the liabilities of owners and operators of aircraft will not be absolute, yet they will be held to such a high degree of care in manufacture, inspection and operation that their liabilities, as a practical matter, will not fall very far short of being absolute.

The Importance of Commercial Aviation

The United States must have a strong, well organized and self-sufficient aviation industry for two essential reasons, military purposes and commercial development. To-day every nation in the world realizes how necessary its military and civil aviation forces are to its safety and welfare. England, France, Japan and Italy are heavily subsidizing their manufacturing and transportation services in order that they may be prepared for the coming military and commercial struggles for air supremacy. No nation can have an adequate air-force in time of war unless it has in time of peace a strong, well developed and efficient commercial industry. Such an industry greatly diminishes the need in time of peace for strictly military equipment, as well as makes possible the production of aircraft for the Government upon a less expensive basis, because of the fact that such production is in quantity. Furthermore, the entire commercial industry, with its aircraft, personnel, landing-fields, airports for seaplanes and flying-boats, and manufacturing and maintenance facilities would be immediately available to the Government.

Commerce involves communication and transportation. Unless a country makes full use of all of its available methods of communication and transportation, it cannot fully develop its commerce. Speed has always been one of the most important factors in commerce and the prog-

[1] Lawyer, New York City.

[2] See Law of the Air by H. D. Hazeltine, p. 52. Aircraft in Peace and the Law by J. M. Spaight, p. 10.

[3] See Constitution of the United States, article 1, section 8.

[4] See United States Supreme Court Reports, vol. 242, p. 160.

[5] See United States Supreme Court Reports, vol. 249, p. 168.

[6] See Constitution of the United States, article 3, section 2; Judicial Code, chapter 2, section 1.

ress of civilization has invariably been from the slow and safer to the faster and, what at first seemed, more insecure means of transportation. Walking, using horses, railroads, automobiles, aircraft, each method was more dangerous than its predecessor, especially at the outset, but as it saved time, it became necessary, and then, popular. The necessary character of aviation is now universally conceded, but it has not yet reached the popular stage due to the still existent feeling that it is solely a war machine, as well as to the high price of aircraft. The latter reason is largely dependent upon the former and as soon as the demand warrants quantity production, aircraft will not cost much more than automobiles. The period of quantity production has not yet come and aviation to-day is where the automobile industry was in 1904. It is ready to develop rapidly in this country under proper stimulus, or to atrophy and pass to other more far-sighted nations if such stimulus is lacking.

One needed stimulus is the provision of landing-fields and similar essential facilities, just as in the case of automobiles road development was a prerequisite to general use. But it must be remembered that the pilot is even more embarrassed by landing in a cornfield than the automobilist was by encountering a muddy country road. For the pilot has no right in the cornfield, and so is responsible for damages to others. Also, he risks life as well as his plane, whereas the automobilist risked a long walk and a few dollars for a team of oxen. It is obvious that the development of landing-fields is essential to the popular use of aircraft. The resources of the United States can be developed and conserved very much further by aviation, and it is of the utmost importance that nothing should be done to injure it but, on the contrary, that it should receive only encouragement.

The Situation in the United States

Commercial aviation is within the scope of this paper and military aviation is not. The matters relating to the control and operation of the Army and Navy Air Forces involve broad issues of national defense and strategy. They are too specialized and complex to be dealt with here. The same is true of the Post Office, Forestry and other Government Departments. Any sufficient consideration of them would be too lengthy for this paper. However, there can be no question that some change should be made in the organization of the various governmental departments which have to do with aviation. For example, aviation is now within the jurisdiction of the Combat Services in the War Department; the Bureaus of Navigation, of Construction and Repair and of Engineering of the Navy Department; the Aerial Mail Division of the Post Office Department; the Bureau of Standards, in the Department of Commerce; the Weather Bureau, in the Department of Agriculture; the Smithsonian Institution and the National Advisory Committee for Aeronautics. The functions of these various bodies might well be simplified and combined

There are some 2000 airplanes in this country and the average number in daily use is about 1500. During 1920 probably about 6000 miles was flown and about 200,000 passengers carried. These estimates are based upon the records furnished by 87 aerial-transport companies. They would be more accurate if every airplane in use was required to be licensed and registered. Commercial aviation is chiefly devoted to the transport of mail, passengers and freight, but is also largely employed for such important services as surveying, forest-fire patrol, timber cruising and photography.

Inspection and Examination

Aviation closely affects the general interests of the community at large. A defective aircraft or an unskilled pilot may expose to danger persons and property not in the aircraft, just as a passing freight-car or ship loaded with explosives or a careless automobile driver might injure the innocent bystander. Danger from others is inherent in community life, but such danger can be minimized. An adequate system of inspection and licensing aircraft, operators of aircraft and landing-fields would remove practically all of the danger in commercial flying. An airplane is unquestionably a dangerous instrumentality and it is useless to endeavor to think of it as anything else. Speed connotes danger. A mass of some 5000 or 10,000 lb. moving at a velocity of 80 to 120 m.p.h. is characteristically capable of accomplishing tremendous destruction. This is as true of an airplane as it is of a train running through a busy switch-yard, a ship coming into a foggy crowded harbor or a high-powered automobile in a street full of pedestrians and vehicles. Moreover, an airplane cannot stop or slow down in case of trouble. It must go on to sustain itself. If it cannot reach the nearest landing-field, greater or lesser damage is almost certain to result. If the design of the structure of an aircraft is wrong, if an important part is carelessly made, or if unsuitable material is employed, great loss of life and property damage may result. This risk must be reduced to a minimum. All aircraft should be compelled to undergo inspection and test for airworthiness before they are allowed to take the air and should thereafter be subject to periodical inspections.

The engineer of a train, the navigator of a ship and the pilot of an airplane each have a tremendous responsibility. A physical defect or mental weakness may cause great destruction. Railroad trains, ships, airplanes and automobiles cannot be discarded because they are dangerous instrumentalities but, on the other hand, the public is entitled to the greatest possible protection and should be given every guarantee that those using these dangerous instrumentalities are fit to do so. Locomotive engineers, navigators and others similarly responsible must pass examinations before they are entrusted with their duties. Operators of aircraft, including pilots and engineers, should be compelled to qualify as such, to take out licenses and to be subject to periodic examinations.

Landing-Fields

Aviation must have landing-fields sufficient in number and character. Safety and convenience in flying depend directly upon aircraft being able to come to the ground on a safe, accessible and well-equipped landing-field, where supplies can be obtained readily and passengers and freight can be transferred easily. If there is no adequate landing-field within gliding distance there may be a certain amount of risk involved, if it becomes necessary for the aircraft to descend because of an unexpected thunderstorm or other emergency. The accessibility of the landing-field is obviously of great importance. A field far removed from the transportation facilities of rail and water communications would be exceedingly inconvenient and of comparatively little value. The management and operation of landing-fields can vary greatly between maximum and minimum efficiency, and unless there is some supervision exercised over them it is quite possible that the unsafe and inefficient ones will predominate. There must be enough landing-fields in this coun-

try and they must conform with certain standards unless the commercial progress of aviation is to be hampered and delayed.

Air-Routes and Rules of the Air

Air-routes are a natural growth of commercial aviation. Their location and nature are controlled mainly by the prospective traffic-density and by the adequacy of terminal facilities, that is, landing-fields. There are other considerations of varying importance, such as the nature of prevailing winds and other meteorological factors, altitudes, etc., but the two first mentioned are the controlling ones. Air-routes are of vital importance to the Nation in time of war. It must be able to mobilize quickly its airplanes and utilize them at points of strategic importance. This is impossible unless air-routes and landing-fields, with their trained personnel and necessary facilities, are in existence as commercial practicalities throughout this country. Commercial and strategic air-routes correspond in the United States. They must be properly laid out by competent authority.

Rules of the air are clearly necessary to avoid collisions and confusion. The respective rights of aircraft meeting or overtaking each other, whether airplane or dirigible or both; what shall be the priority in taking-off or landing; what lights shall be carried and how, and a great many other similar matters should be determined and made binding upon all aircraft. Otherwise, unnecessary accidents will occur with ensuing damage to aircraft, their contents and what is beneath them. Rules and regulations are requisite also to prevent low flying or acrobatics over populated districts. Such regulations are in force in other countries. They are in force in some towns and cities here but, as they are not uniform, they should be superseded by Federal regulations which would be uniform everywhere.

Aeronautical Safety Code

Insurance of aircraft and personnel is necessary before full commercial development can be attained. It is as true of the aviation industry as of other industries that the individual cannot afford to be uninsured. Full insurance protection in aviation with a reasonable system of rates cannot be had until there is proper Federal control.

In consideration of the foregoing matters, we must not omit reference to the fact that the art of aeronautics is not yet standardized. It is undergoing constant improvement, based upon laborious and costly scientific investigations, which will undoubtedly continue for some years. Its individual and peculiar arrangements can only be met satisfactorily by a flexible set of rules and regulations, composed and administered by capable and experienced persons. A new discovery may render obsolete in a week rules which, if allowed to remain unchanged, would immeasurably interfere with the progress of the art and industry. No rules or regulations should be enacted until careful consideration has been given to the needs of the complex and difficult situation and those interested have had an opportunity to present their views.

It is important to note that the Bureau of Standards has already prepared a partial tentative draft of an American Aeronautical Safety Code, containing a thorough, well-laid-out plan of safety regulations. Airplanes, aviators, powerplants, signals, traffic and flying rules and landing-fields are given detailed and able consideration. This draft is being considered by a committee of this Society and, when issued in final form under the auspices of the various organizations interested in aeronautics, will unquestionably be a most valuable contribution to the art and industry.

The Character of the Administrative Body

The particular legal status of the body which should formulate and administer the necessary rules and regulations and provide for the licensing of aircraft, operators and landing-fields does not seem to be essential, provided it is competent and authoritative. It may conceivably be a separate board, such as the Shipping Board or Federal Trade Board. This is the Canadian organization. It may be a Secretary of Civil Aviation, as is the case in England, or it may be a sub-department in an existing department, such as the Department of Commerce. Each of these possibilities has been suggested and each has its individual merits and defects.

The fundamental question appears to be, not what shall be the title of the two or three men who will actually do the work, but rather what will be their ability, powers and functions. It is the purpose of this paper only to indicate what powers and functions a suitable body should have, regardless of the form or title it may take. It is essential, of course, that it should be vested with sufficient authority and responsibility to enable it to make its own decisions and enforce its own policies without being compelled to seek the approval of any other department or board. It must be able to stand on its own feet or it will not be able to accomplish anything constructive or desirable, and only hopeless confusion will result. It is highly desirable that the Army, the Navy, the Post Office and the Department of Commerce should be actively represented. Each of these departments is vitally concerned with the welfare of commercial aviation and is also in a position to further greatly its interests. They should be in a position to present their views directly and effectively to the controlling body.

Nature and Scope of Immediate Federal Legislation

A body should be immediately constituted by Act of Congress, which for convenience will be referred to herein as a Board, which should have the authority to

(1) Investigate, from time to time, aviation conditions in and with foreign countries, appoint representatives at such international aerial conferences as to the Board may seem advisable, and report to Congress thereon with such recommendations as seem advisable
(2) Establish or supervise aircraft routes and ways and the regulations which shall govern the traveling of such routes and ways
(3) Grant or refuse licenses for aircraft in response to a written application therefor which shall set forth the data requested by the Board
(4) Grant or refuse operators' licenses to pilots, engineers or other operators of aircraft in response to a written application therefor which shall set forth the data requested by the Board
(5) Grant or refuse landing-field licenses in response to a written application therefor which shall set forth the data requested by the Board
(6) Revoke licenses for aircraft, operators or landing-fields upon determination by the Board that its requirements and standards are not being complied with
(7) Make all necessary rules and regulations to carry out the above provisions

Licenses for aircraft, operators or landing-fields should

not be granted unless the Board considers that the applicants meet the requisite tests. Suitable penalties should be provided for the operation of unlicensed aircraft or landing-fields and for violating any of the rules and regulations of the Board with respect to air-routes or other matters. Privileges should be granted to foreign aircraft and operators in the discretion of the Board, provided their nations extend similar privileges to licensed American aircraft and operators.

It sometimes occurs that commercial aircraft are compelled in an emergency to land on or near a military or naval landing-field. Because of the vital importance of commercial aviation to the safety of the country, the Secretaries of War and the Navy should be authorized to sell such gasoline, oil and other aircraft supplies as can be spared without detriment to the military service at not less than the contract price plus 25 per cent to cover the cost of purchase and inspection.

The constitutionality of the proposed legislation has been carefully examined and it is the opinion of eminent lawyers that it would be constitutional. A broader plan might or might not be and might also cause opposition, which would delay and perhaps seriously interfere with the enactment of the desired Federal legislation. The essential thing is to make a beginning and then expand as experience teaches. The art is still too much in the growing period to call for a fixed system.

The International Aerial Convention of Oct. 13, 1919, has fallen with the League of Nations, of which it was a part. It is still of some importance, however, as it is proposed to hold a meeting of aviation representatives of the allied and associated powers in London this year, to consider aeronautic matters, and the question will be suggested as to whether the United States should join this part of the League of Nations. It is not within the scope of this paper to consider this matter. Nevertheless, it may be pointed out that the conditions in the United States are essentially different from those in England, France, Italy or other continental nations where the national boundaries are limited and aircraft are constantly passing from friendly to neutral or hostile countries. An elaborate system of navigation rules, customs regulations and other legislation is neither necessary nor desirable in the United States. So far as possible, the rules and regulations in this country should conform to the standard practice abroad, but it is obviously highly undesirable that commercial aviation in the United States should be controlled by an International Commission for Air Navigation, probably sitting at Geneva, and in which the United States would have a small minority voice.

In conclusion, it must be repeated that there is urgent necessity to-day of a carefully formulated and well-administered plan of Federal legislation, which will take care of the immediate and future requirements of the vitally important and fast-developing aviation industry.

Viscosity

IF a bucketful of water is tipped until the water is about to spill and then suddenly released so that it will resume its horizontal position, the water will oscillate from side to side. Each oscillation will be of less and less amplitude until the water is finally at rest with its surface horizontal. If the same experiment be tried with an engine oil it will be found to come to rest much sooner than did the water. If this experiment is repeated with a cylinder oil the liquid will come to rest with practically no oscillation at all. In all cases the oscillation ceases sooner or later and it is the internal friction or viscosity of the liquid that stops the motion. In other words, although liquids can be made to assume any shape they offer a certain internal resistance to being moved or disturbed and this is the property, called viscosity, that interests us.

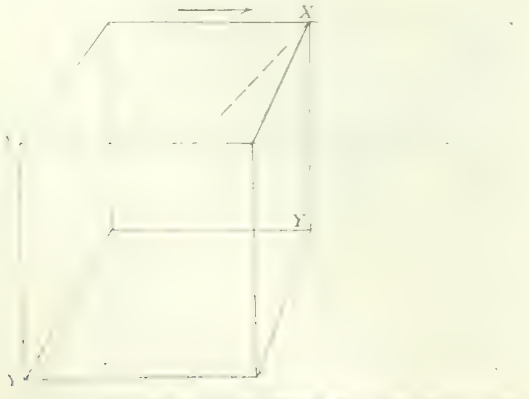

Diagram Showing How Fluid Is Supposed To Be Employed To Measure the Absolute Viscosity of a Liquid

There are many ways of measuring viscosity in liquids. The purely scientific way is to determine the absolute viscosity of the liquid. The absolute viscosity of a liquid can be explained as follows: In the accompanying illustration let *XX* and *YY* be two plane surfaces a given distance apart and between the two surfaces is placed the liquid, the absolute viscosity of which it is desired to measure. The surface *YY* is kept stationary and the surface *XX* moved at a given velocity in the direction of the arrow so that it will, after a time, assume the position shown dotted. The force required to maintain this motion, that is, the force required to distort the liquid at this rate is a measure of the absolute viscosity. If the surfaces *XX* and *YY* are each 1 sq. cm. (0.155 sq. in.) in area and 1 cm. (0.3937 in.) apart and the surface *XX* is moved at a velocity of 1 cm. (0.3937 in.) per sec., the force in dynes required to maintain this rate of motion is the absolute viscosity. The unit of absolute viscosity is called a "poise."

It is much easier to measure the flow of a liquid through a pipe by noting the time required for a certain quantity of liquid to pass. There has been developed a formula giving the relation between the absolute viscosity of a liquid and the quantity discharged through a tube of small diameter. Many practical instruments for measuring viscosity have been proposed. The three of greatest importance in oil measurements, however, all depend on the time it takes a given quantity of oil to flow through a certain sized orifice of a tube. They are the Redwood instrument used largely in England, the Engler used in Germany and sometimes in the United States, and the Saybolt used by a large number of the oil companies operating in this country.—J. Maris in *Petroleum Magazine*.

Cooperation in Research

By Walter E. Lay[1]

Semi-Annual Meeting Paper *Illustrated with* Photographs and Drawings

During the war research and scientific investigation of everything having a possible relation to the great conflict were conducted on a scale never before attempted. The war has been called the war of engineers and scientists. It might well be called the war of the automotive industries, in which development work was particularly intense. Now that the big problem has apparently been solved there is no less a need for continued work of this nature. It is true, of course, that in the reconstruction period the most rigid economy is necessary. But research work carried on with the full utilization of all present facilities will ultimately be an economy. It always has been an economy ultimately.

From time immemorial the seat of learning, the school, has been also the center of research. Gradually through the painstaking efforts of men at educational centers has the complex mass of known facts been gathered, arranged and classified to form the body of what we call the sciences. It is necessary for every modern scientific school or college to maintain laboratories where work can be done by the student, which proves how certain principles and theories hold true and also shows him their limitations in practical application. There is in the United States a large quantity of such equipment available for accurate scientific investigation and in most cases it is now being used in that way. There have also grown up in various industries large and very completely equipped laboratories. In the case of the automotive industry their work has been a very important factor in the phenomenally rapid development of the automobile.

Industrial and Technical School Research

There seems to be a fundamental difference between industrial and technical school laboratory work. The reason for this can be traced back to the incentive behind the endeavor. The work done in an industrial research laboratory is carried on with the idea of immediate improvement of the product or the development of new products. At the college laboratory the incentive is often purely a desire to explore which finds expression more or less in the work of any human being. Too often this work has been done without taking into consideration whether it would have an immediate practical application or indeed ever prove of value to mankind. However, it will be admitted that in general the work is done in a thorough and conclusive manner. The university, at which every one is searching for knowledge, has an atmosphere conducive to the complete solution of problems in all their details. The work is carried on in a manner at once painstaking and accurate without serious interference or time limit and should give results conclusive beyond question.

In the experimental laboratory real research is carried on but there is always a tendency to side-track it to give way for makeshifts which will temporarily satisfy the demands of the public or the sales force and return a satisfactory profit. Seldom indeed can the engineer attack a problem, carry out his investigation until all possibilities have been exhausted, and bring the work to a successful conclusion. There are some types of work which can best be done in an industrial laboratory and probably will always be done there. On the other hand, some research work can very properly be done at the laboratories of our universities and technical colleges. When so many different laboratories are engaged on similar or related problems, one would think that considerable economy of effort could be effected by a proper coordination of the work done by both industrial and school laboratories. It might be somewhat difficult for a central organization to direct the procedure, but much good could be accomplished by keeping each organization acquainted with the equipment developed and the current results obtained by the others.

There are general investigations which can be taken up by the industry as a whole and it is perhaps this kind of subject that can be handled best in a laboratory of a State university or technical college. The University of Michigan by virtue of its location in the center of the automobile industry should be among those considered for work along these lines. The accompanying statistics taken from *Automotive Industries*[2] on the distribution of automobile and truck builders will help to make this clear. In the same magazine the daily production of cars by the leading motor-car builders in August, 1919, was reported. Twenty-six of the 34 listed were located in Michigan and had a total daily production of 5574 cars or approximately 1,670,000 for the year. As the year's production for the whole United States was under 2,000,000, Michigan produced more than three-fourths of the automobiles built in the United States for the year 1919.

Distribution of Automobile and Truck Builders

State	Automobile Builders Number	Automobile Builders Rank in United States	Truck Builders Number	Truck Builders Rank in United States
Michigan	34	1	53	1
Ohio	25	2	32	3
Illinois	16	4	40	2
Indiana	20	3	13	6
Total for group	95		138	
Total for United States	167		300	
Percentage in group	57		46	
Percentage in Michigan	20		18	

Automobile Laboratory at University of Michigan

There has been at the University a gradual development of laboratories and equipment for use in teaching engineering science with particular reference to its application to problems met in the design and operation of automotive vehicles. Among these is the automobile division of the mechanical laboratory. This section quickly

[1] M. S. A. E.—Assistant professor of mechanical engineering in charge of automobile engineering, University of Michigan, Ann Arbor, Mich.

[2] See *Automotive Industries*, Aug. 28, 1919, p. 406.

outgrew the space allowed in the main laboratory and this year moved into one of the cantonment type of buildings used for training army mechanics during the war, occupying a floor-space 60 x 120 ft.

This laboratory is divided into three sections, a classroom, a general laboratory for routine testing and demonstration which is shown in Fig. 1 and a research room where accurate mechanical testing and investigations can be carried out. The classroom is supplied with tables, charts and data books needed in computing the results of experimental tests. The second section is equipped with seven engine testing-stands and three water-dynamometers of from 20 to 60-hp. capacity and one calibrated fan-brake.

The water-dynamometers are mounted on a track so that they can be easily moved to position at the rear of any engine where they are fastened in approximate alignment by two holding-down tee-bolts. The dynamometer

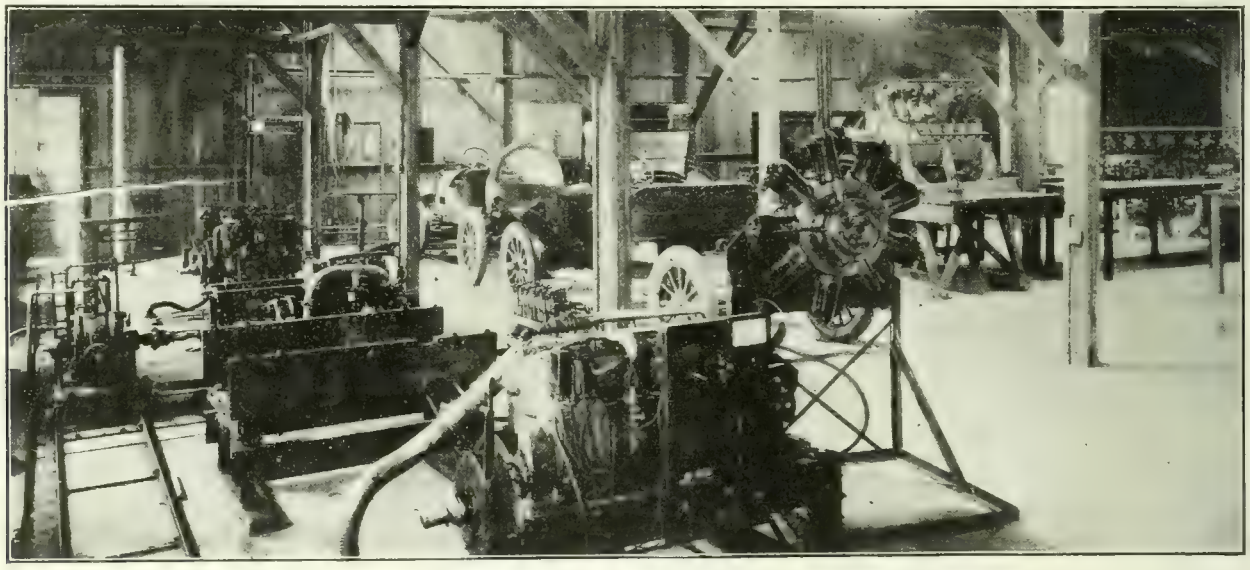

Fig. 1—General Automobile Testing Laboratory

is connected to the engine by a drive-shaft with two metal universal-joints. The shaft is splined at both ends. Both engines and dynamometers are fitted with the same universal-joint unit which is fitted to receive the splined ends of the shaft. To disconnect the dynamometer from the engine it is necessary to loosen the holding-down bolts and move the dynamometer down the track until one universal-joint slides free from the shaft. Then the shaft can be removed entirely and held ready to go into place as the dynamometer is aligned with the next engine. Water for cooling the engines and the dynamometers is furnished through two pipes on the wall, one supplying cold water and the other water at any desired temperature from cold to near the boiling-point. If the engine is air-cooled conditions similar to those in operation on the road are obtained by use of a portable Sirocco blower driven by a direct-connected electric motor. Fuel is supplied from 10-gal. tanks mounted on light stands supplied with large casters so that they can be rolled to the gasoline pumps for refilling when necessary.

There are available for demonstration and tests over 20 engines varying in size from the Ford to the Liberty aviation engine. Two chassis are used for car-performance tests including hill-climbing, acceleration and economy of fuel over the driving range. In addition, there is mounted on demonstrating racks considerable equipment, including carbureters, ignition systems, governors, clutches, transmissions and rear axles.

The third section, the research room, includes among its larger equipment a 100-hp. and a 60-hp. electric dynamometer, a set of chassis testing drums, a drawbar pull dynamometer and a motor-generator set. The dynamometers are fully equipped with switchboards, load resistances, control rheostats, beam-scales, tachometers and electrically operated revolution-counters to be used in conjunction with the fuel measuring apparatus. The important feature of this room is the layout of the dynamometers and testing-floor to use the dynamometers to their full capacity as shown in Fig. 2. It had been found in previous years that when a complicated set-up had been built up for special work the dynamometer could not be used for any other work without tearing down the set-up and making a new one. So when the new laboratory was laid out the pedestals of the dynamometer were mounted in a flat circular bedplate or base with a circular groove on its under surface. A similar base was set in the concrete with a corresponding groove in its upper surface. These grooves are filled with ¾-in. steel balls and form a bearing upon which the dynamometer can be turned to align its shaft with any one of the four testing-bases or the countershaft driven by the chassis drums. The dynamometer is located exactly by two dowel pins directly under its shaft. The relative position of the dynamometer and engine bases is illustrated in Fig. 3.

Metal universal-joints and a drive-shaft splined at both ends are used here as well as on the water-brakes. As the dynamometer is rotated on its base, the distance between the universal-joint on the dynamometer and that on the engine is increased until one splined end of the shaft comes free from its universal-joint. The shaft can then be readily removed and placed in position on another engine so that it goes into place as the dynamometer is brought into alignment with it. Thus the dynamometer can be disconnected from one engine and connected to another in 5 or 10 min.

The chassis-testing outfit, which has not been put in place, consists essentially of two drums, having a wood surface 6 ft. in diameter and 18 in. wide, which are mounted on large shafts at the proper distance apart to

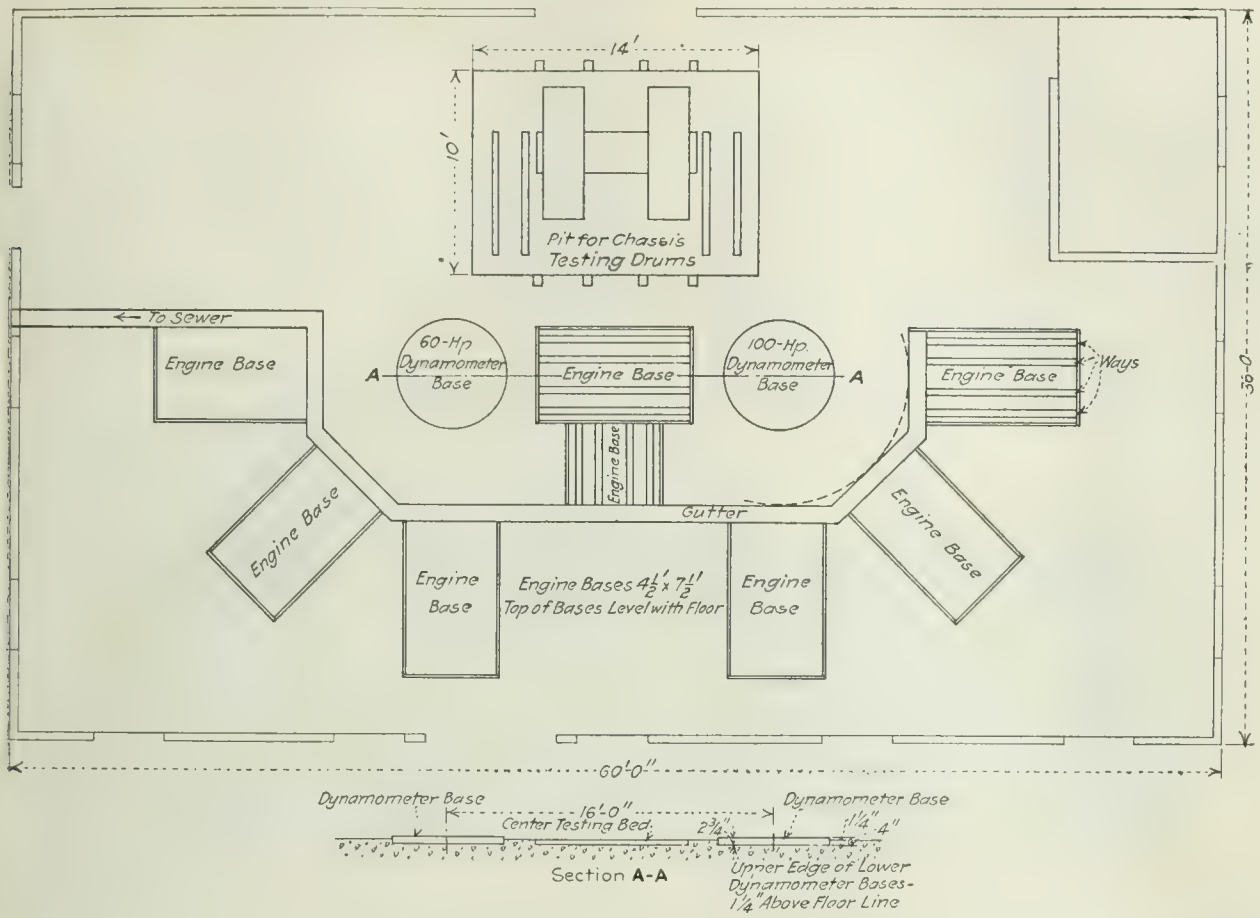

FIG. 2—LAYOUT OF APPARATUS IN THE DYNAMOMETER ROOM

correspond with the track of an automobile. The outer end of each shaft is splined and will fit the axle drive-gears of a 5-ton truck differential-carrier assembly in place of an axle-shaft. This in turn will drive a heavy gearset which drives the dynamometer through silent chains as outlined in Fig. 4. The dynamometers can thus be driven at the same speed as the engine and easily absorb the output. The net power-output of a chassis can be determined by measuring the pull of the car with a drawbar dynamometer and determining the peripheral speed of the drums.

The motor-generator set is used to furnish direct current to operate the electric dynamometers. The motor, being of the synchronous type, is not affected by variations of voltage and will maintain a constant speed of the electric generator and a constant voltage at the dynamometer switchboard.

Among the more interesting details might be men-

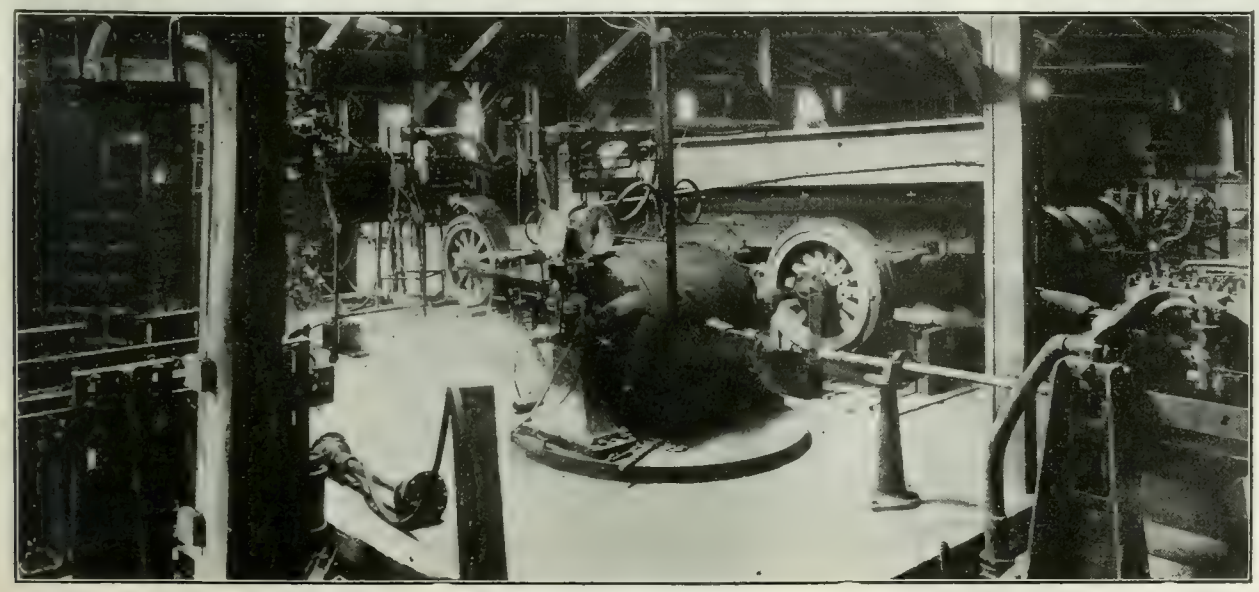

FIG. 3—DETERMINING THE EFFICIENCY OF THE TRANSMISSION SYSTEM IN THE DYNAMOMETER ROOM

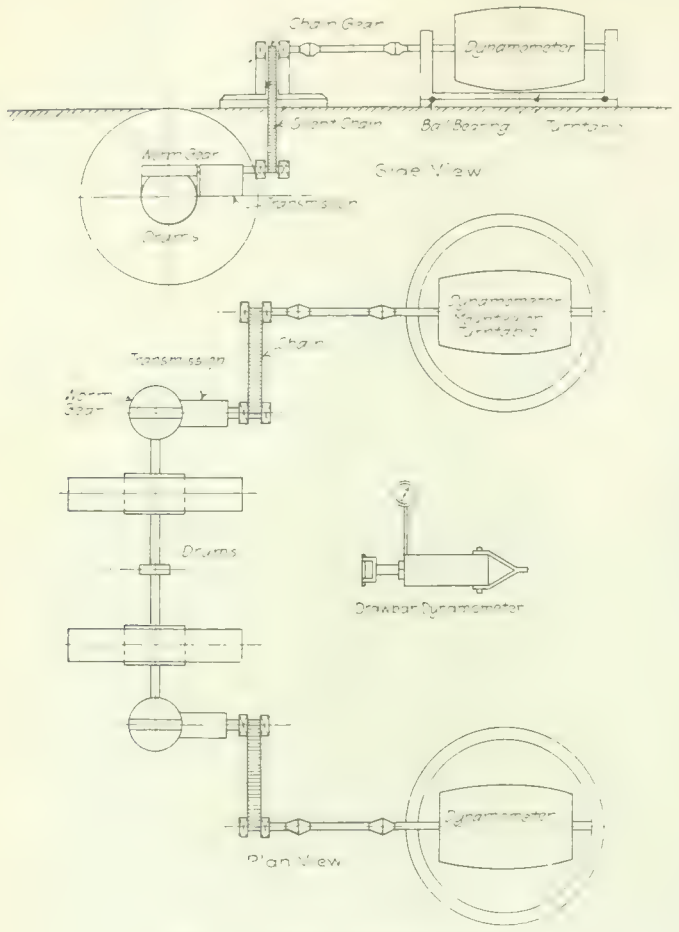

FIG. 1—CHASSIS TESTING OUTFIT

tioned the arrangement of the controls of the dynamometer and engine set-up shown in Fig. 3. In front of the scale-beam is a table supported by the dynamometer base. The field-rheostats or load and speed controls have been placed under this with the control-wheels above. A throttle and spark-control quadrant is located on the post just above the table and the large tachometer is only 2 ft. from the eyes of the operator. This brings all controls within easy reach and with the dynamometer in any of its positions the switchboard is never more than two steps from the operators' position at the control table.

The engine bases are built up of four slotted rails bolted rigidly to 2-in. angle-iron and the whole embedded in a concrete slab separated from the rest of the floor by planks. If the engine being tested develops excessive vibration, it is not communicated through the floor to the dynamometer or any of the weighing apparatus. The gutter shown between the engine and dynamometer bases carries off the water and contains the main exhaust and hot and cold-water pipes. By a suitable arrangement of valves water is delivered from the outlet through garden-hose to the engine jacket, the radiator or cooling tank at any desired temperature.

With this arrangement the dynamometer is made to serve a variety of purposes without building new parts for each test or disarranging it to such an extent that it cannot be made to handle a different kind of work in a short time. In other words, it has been made somewhat universal. There is space between the dynamometers for mounting a transmission so that one dynamometer can drive the transmission and the other absorb the output, thus measuring both the input and the output and determining the mechanical efficiency. A rear-axle can be mounted between them and driven by an engine on a reaction dynamometer so that the efficiency of the final-drive and the action of the differential can be determined. In Fig. 3 a truck is shown jacked-up with each rear-axle jackshaft connected to a dynamometer. Here the efficiency of the transmission system, including the universal-joint shafts, transmissions, final-drive, and the bearings in the differential-carrier, is being determined. There is room for six engines to be mounted at the same time. This will allow one engine to be set up while tests are being made on another if necessary.

OTHER RESEARCH EQUIPMENT

There is available for use in connection with the above-mentioned equipment special fuel-measuring devices with electrically operated revolution-counters and stop-watches, meters for measuring air and water, pyrometers, gas-analysis apparatus, a manograph, indicators and complete accessories necessary for doing accurate research work. In the study of engineering materials used in the construction of the automobile the chemical laboratories are very important. The laboratory equipment for work in metallurgy and metallography is extensive. Ample facilities are provided for the microscopic study of metals. A new photomicrographic camera is to be added.

Electric furnaces are used largely for heat-treatment of metals but there are also oil and gas-fired furnaces of various capacities. Lead pots and various salt-baths are available whenever desired. The pyrometer laboratory has a large equipment of various types of temperature-measuring device. This includes several types of thermo-electric and optical pyrometer. A platinum-rhodium thermocouple, which has been standardized recently by the Bureau of Standards, is used as an ultimate standard for maintaining all the other instruments in an accurate condition. A precision potentiometer is used in calibrating all thermocouples for use about the laboratory. For work in electrometallurgy and electrothermal studies direct and alternating-current lines are available. A specially designed switchboard and transformer make a very flexible outfit for use in constructing carbon resistor furnaces. The gas and fuel laboratories are equipped with all necessary apparatus for gas-analysis and fuel-testing. This includes several types of gas burette, bomb calorimeters and other more specialized apparatus.

In the physical testing laboratory apparatus is provided for testing the strength of materials used in engineering work. This equipment includes a 100,000-lb. Olsen testing machine and one of 200,000-lb. capacity built by Riehle Bros. Both of these machines are adapted to tensile, compressive and transverse tests and are run by direct-connected electric motors. An Olsen machine of 240,000-in-lb. capacity, also equipped with a direct-connected motor, is used in determining the torsional strength of shafts and axles. Impact tests are made on an Olsen impact-machine, and an Upton-Lewis toughness-testing machine is used for endurance tests.

It is our belief that these facilities should be utilized more fully. The Society has established a research committee and there is slowly being developed at the University of Michigan a Bureau of Industrial Research whose purpose it is to coordinate, if possible, the efforts of industrial laboratories in Michigan with those of the University.

Activities of the Sections

THERE appear in this issue pictures of the officers of all of the Sections. These men assumed office in May and will direct the programs of their respective Sections for the coming year. Members do not perhaps always realize the arduous work that is done and the considerable amount of time which is devoted to it by the Section officers. The success of the Sections throughout the year will depend largely upon the support given to these officers by the other members.

The plans outlined at the Summer Meeting of the Society for arranging the schedules for the Sections early in the season are being worked out. The Dayton, Detroit, Metropolitan, Mid-West and Pennsylvania Sections have selected the subjects for most of their meetings and in some cases have secured the speakers. The remaining Sections expect to announce their plans shortly.

No technical sessions will be held until September. A number of the Sections have however arranged to hold outings during the summer. These are always popular additions to the season's program.

Last season a number of plant visits were made, including that of the Metropolitan Section to the yards of the Consolidated Shipbuilding Corporation, the Pennsylvania Section's trip to the Navy Yard at Philadelphia and the inspection of the Rolls-Royce factory at Springfield by the New England Section. Similar visits will be made by various Sections this year. Some of these will be joint meetings of Sections. An invitation has already been accepted by the Society to visit the Aberdeen Proving Ground on Oct. 7, and several of the Eastern Sections plan to take this trip in place of holding their regular October meeting. An announcement of this trip appears on page 84.

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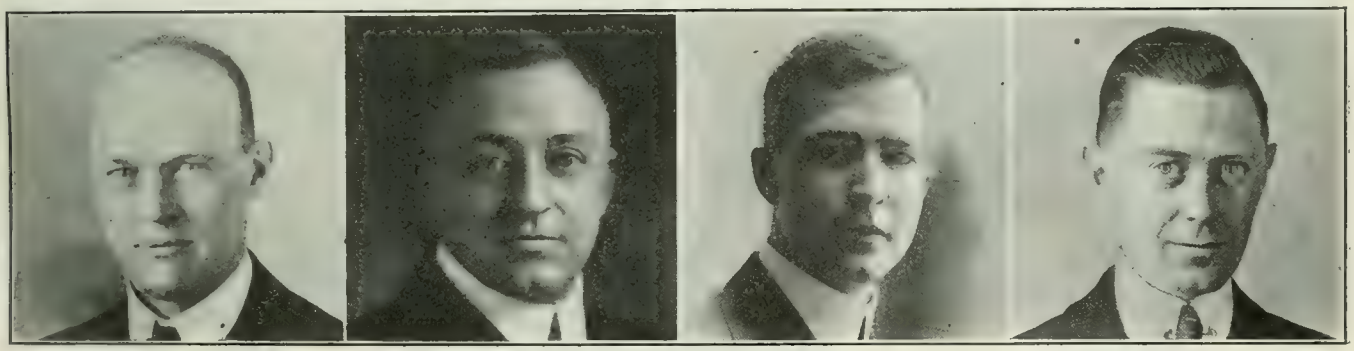

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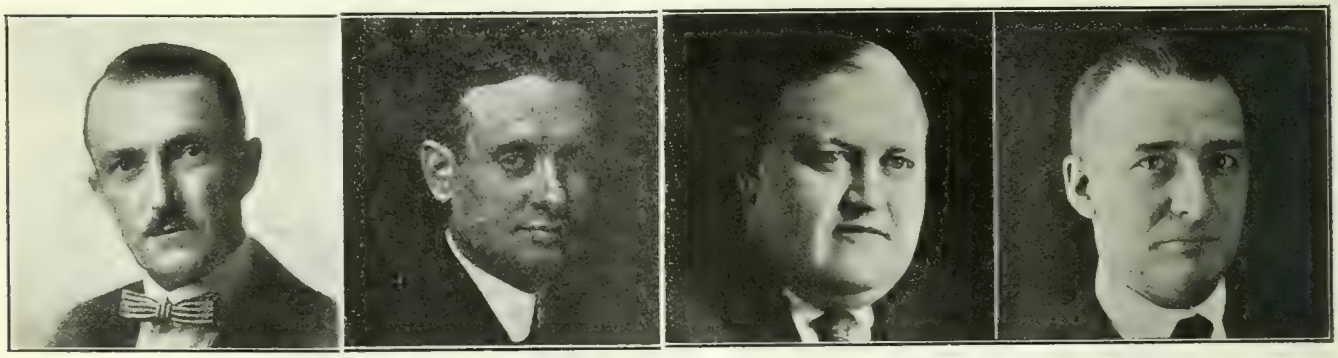

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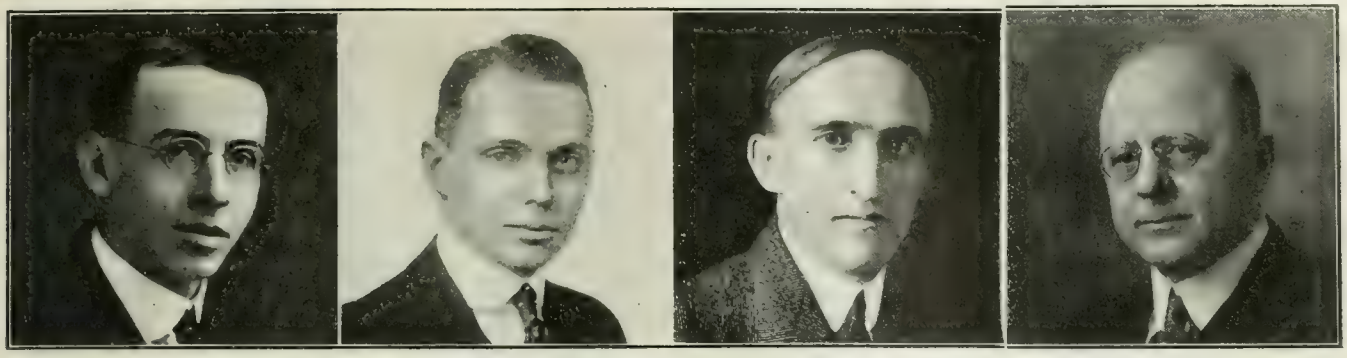

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Applicants *Qualified*

The following applicants have qualified for admission to the Society between June 10 and July 11, 1921. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

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Representative:
Miller, J. O., assistant factory superintendent.

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Publications of Interest *to* S. A. E. Members

In this column are given brief items regarding technical books and publications on automotive subjects. As a general rule, no attempt is made to give an exhaustive review of the books, the purpose of this section of THE JOURNAL being rather to indicate from time to time what literature relating to the automotive industry has been published with a short statement of the contents.

AN ANALYSIS OF THE REPORTS OF THE NEBRASKA TRACTOR TESTS. By E. A. White. Published by *Farm Implement News*, Masonic Temple, Chicago. 76 pages.

In this reprint there is given the official report of 65 tractor tests conducted at the University of Nebraska. The reports proper are preceded by an analysis of the results with graphs and tables illustrating fuel consumption, thermal efficiency, governor variation, and drawbar pull. One table is presented giving the volumetric, thermal, friction and belt efficiencies of all the tractors tested.

STRENGTH OF SCREW FASTENINGS IN PLYWOOD. Technical Note No. 149. Published by Forest Products Laboratory, Madison, Wis. 2 pages.

If the screw fastenings in plywood construction are to be as strong as the plywood itself, it is important to adapt the size of screw, spacing, and margin to the particular species and thickness of plywood used. Tests made at the Forest Products Laboratory have shown that the commonly-used plywood species may be divided into three groups, all woods in any one group requiring the same screw fastening to develop maximum strength. A table gives the recommended screw sizes, margin and spacing for use with each group and plywood thickness.

COMPARATIVE TESTS OF STEELS AT HIGH TEMPERATURES. By R. S. MacPherran. Paper read before the American Society for Testing Materials, 1315 Spruce Street, Philadelphia. 9 pages.

The tests recorded in this paper were made to determine the comparative properties of various steels at high temperatures with a view to obtaining information as to the best material for use under operating conditions of 600 to 1000 deg. fahr. These tests were made on carbon and alloy steels, both rolled and forged. While the tests would not warrant the drawing of any definite conclusions, they, at least, throw considerable light on the subject and indicate that further consideration should be given to the properties of various alloy and carbon steels at high temperatures.

CARE AND USE OF THE HYGROMETER IN KILN DRYING. Technical Note No. 148. Published by Forest Products Laboratories, Madison, Wis. 2 pages.

Several basic practices are suggested in this note for the proper handling and correct use of hygrometers in the interpretation and regulation of kiln conditions.

THERMAL EXPANSION OF COPPER AND SOME OF ITS IMPORTANT INDUSTRIAL ALLOYS. By Peter Hidnert. Scientific Paper No. 410 of the Bureau of Standards. Published by Superintendent of Documents, Government Printing Office, Washington. 159 pages.

Data on the thermal expansion of 128 samples of copper and its important alloys of various compositions, heat-treatments, mechnical treatments, etc., are presented. The specimens contained from 56 to 100 per cent of copper and were prepared in a number of ways; cast, cast and cold-rolled, extruded, extruded and cold worked, hot-rolled and cold worked. Most of the samples were examined from room temperature to about 300 deg. cent. (572 deg. fahr.). Practically all the available information on the thermal expansion of copper and its alloys is briefly reviewed. Definite mathematical relations were found to exist between the coefficients of expansion and the copper content of most of the alloys investigated. In general, the coefficient of expansion increases with a decrease in the copper content. The addition of lead or tin has a decided effect on the coefficient; the former element generally decreases and the latter increases the coefficient. The appendix gives average coefficients of expansion of all the samples investigated.

REMOVAL OF GLUE STAINS. Technical Note No. 146. Published by Forest Products Laboratory, Madison, Wis. 1 page.

Casein and vegetable glues containing caustic soda produce stains on certain kinds of wood, notably the oaks, maple, cherry, elm, ash, birch and beech. The staining is due to the action of the alkali in the glue on the constituents of the wood forming a substance related to ink. No means have yet been found of preventing this chemical action but this note describes precautions which can be taken to keep the discoloration from the finished surfaces.

SOME FACTORS OF AIRPLANE ENGINE PERFORMANCE. By Victor R. Gage. National Advisory Committee for Aeronautics Report No. 108. Published by the National Advisory Committee for Aeronautics, Washington 29 pages.

This report contains the results of a search for fundamental relations between many variables of engine operation. The data used came from over 100 groups of tests made upon the Liberty 12-cylinder and three models of the Hispano-Suiza engine in an altitude chamber, where conditions simulated altitudes up to about 30,000 ft.; with engine speeds ranging from 1200 to 2200 r.p.m. and compression ratios ranging from under 5 to 1 to over 8 to 1. The data taken on the tests were exceptionally complete, including variations of pressure and temperature, besides the brake and friction torques, rates of fuel and air consumption, the jacket and exhaust heat losses. It was found that the friction torque increases approximately as a linear function of engine speed at a given air density and that the friction horsepower increases approximately as the square of the speed. The data indicated that the pumping losses are about half of the total friction. For a given process of combustion and at a constant speed the engine power proved to be directly proportional to the weight of the charge supplied; in other words, proportional to the charge density at the beginning of compression. The volumetric efficiency increases with an increase of the air temperature at a constant pressure, so that power does not decrease as fast as the air density when the temperature is raised, due to changes in vaporization and heat transfer.

SOME MECHANICAL PROPERTIES OF HOT-ROLLED MONEL METAL. By P. D. Merica, R. G. Waltenberg and A. S. McCabe. Paper read before the American Society for Testing Materials, 1315 Spruce Street, Philadelphia. 2 pages.

Mean values of the tensile properties of hot-rolled or hammered monel metal rods are computed from the results of 500 tensile tests. The average proportional limit of hot-rolled monel metal varies from 35,000 to 49,000 lb. per sq. in., and is approximately 80 per cent of the yield-point. It possesses a remarkable degree of toughness as compared with other metallic materials, including alloy steels. The average proportional limit in torsion, or shear, varies from 20,000 to 29,000 lb. per sq. in., or from 55 to 67 per cent of that in tension. This metal will withstand approximately 75,000,000 alternations of tension and compression at a maximum fiber stress of 38,000 lb. per sq. in. and approximately 2,000,000 alternations at 43,000 lb. per sq. in. The alternating stress tests were carried out at the Bureau of Standards by Mr. Waltenberg; the other tests were made at the research department of the International Nickel Co.

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. IX September, 1921 No. 3

The Committee Organization of the Society

THE work of the Society is carried out largely through committees working under the direction of the Council in accordance with the Constitution and By-Laws adopted by the membership. Figs. 1 to 5 show these committees and indicate their organization and the procedure followed in adopting reports.

In several of these charts the Society Business Session or Meeting has been given the status of a separate committee. This has been done as the Constitution states that an act of the Council that shall have received the expressed or implied sanction of the membership at any subsequent Society Meeting shall be deemed to be the act of the Society and shall not afterwards be impeached by any member.

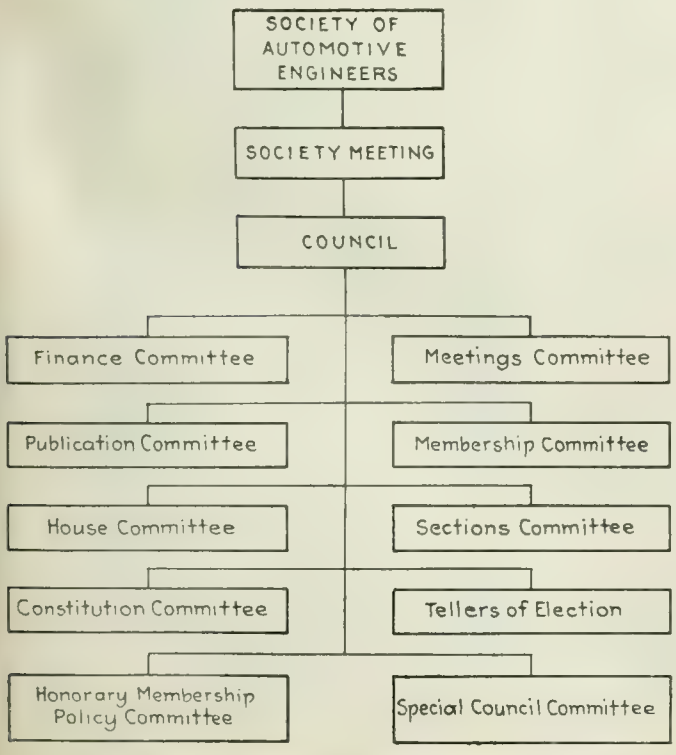


FIG. 1—ADMINISTRATIVE AND SPECIAL COMMITTEES

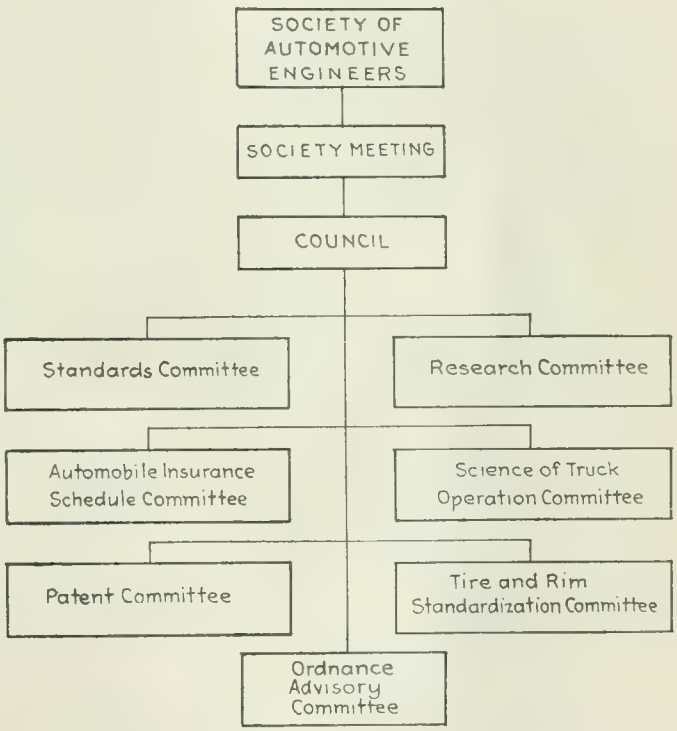


FIG. 2—STANDARDS AND PROFESSIONAL COMMITTEES

The Council may also order the submission of any report to the membership by letter ballot. As the Standards Committee work is of vital interest to the members, the Council has ruled that all Division reports approved at a Society meeting shall be submitted by letter ballot to the voting members of the Society.

ADMINISTRATIVE COMMITTEES

Seven administrative committees are appointed annually by the President of the Society within 30 days after taking office from the individual membership of the So-

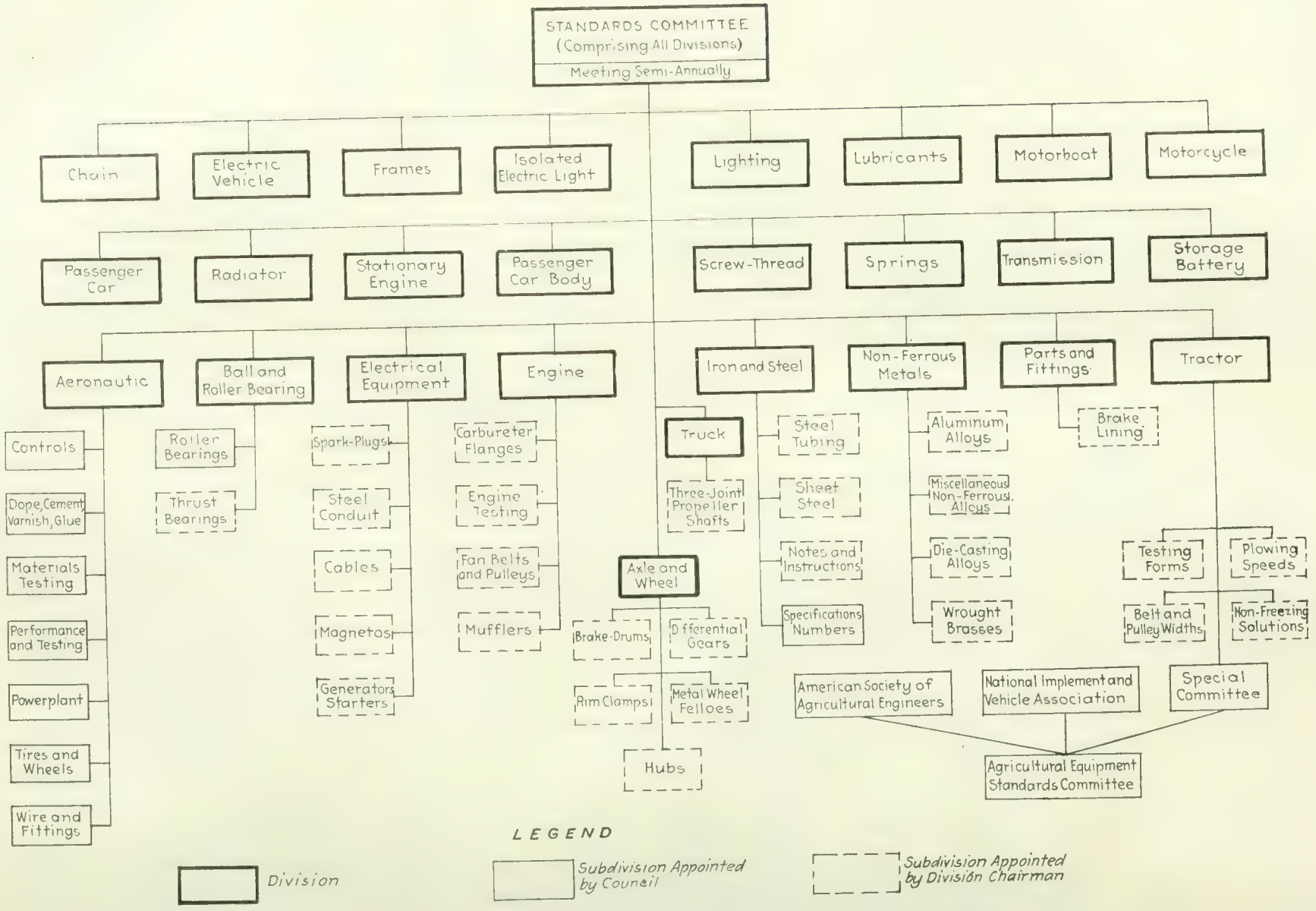


FIG. 3—ORGANIZATION OF THE STANDARDS COMMITTEE OF THE SOCIETY

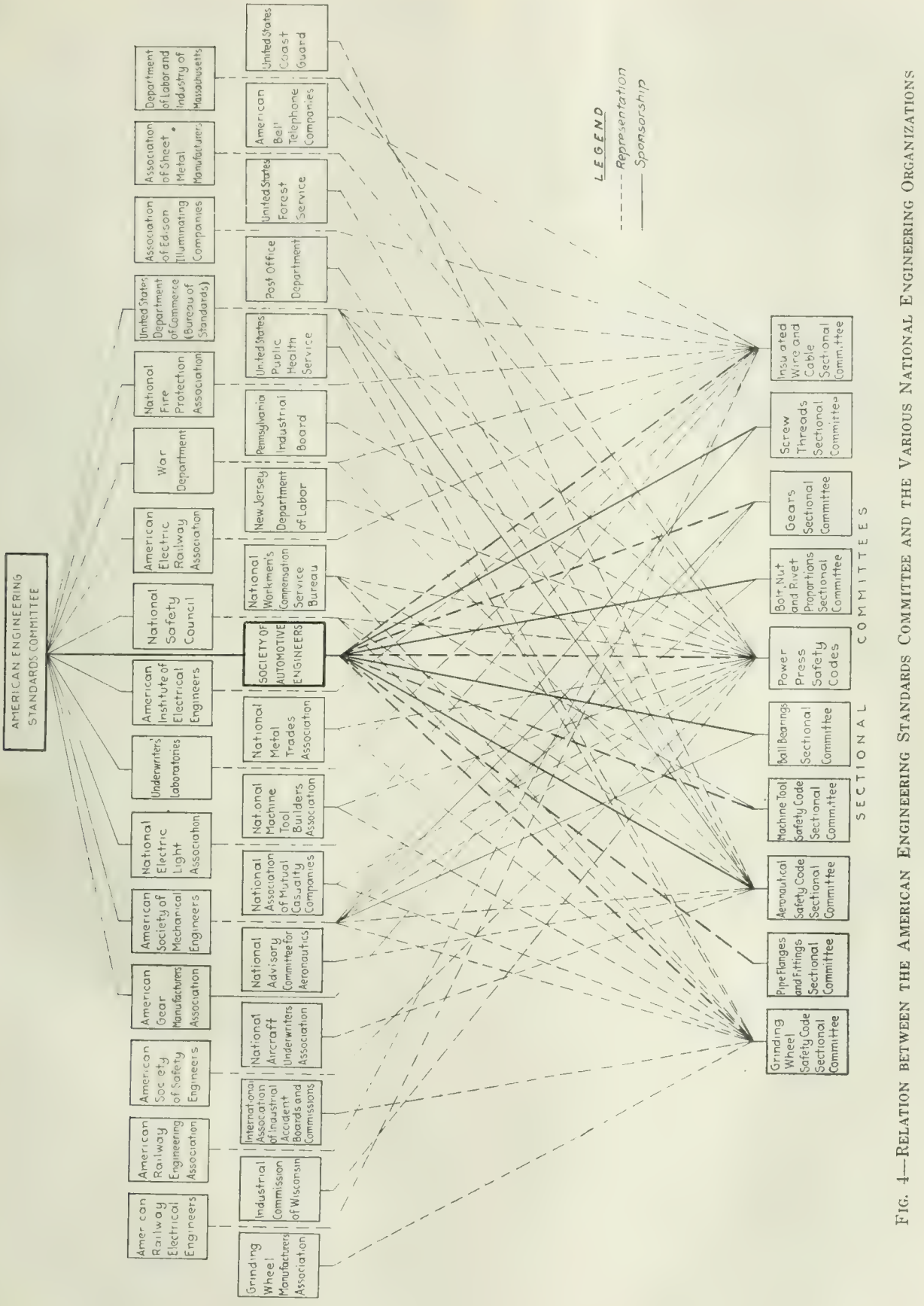

AMERICAN ENGINEERING STANDARDS COMMITTEE
SOCIETY OF AUTOMOTIVE ENGINEERS
LEGEND
Representation
Sponsorship
SECTIONAL COMMITTEES
Grinding Wheel Safety Code Sectional Committee
Pipe Flanges and Fittings Sectional Committee
Aeronautical Safety Code Sectional Committee
Machine Tool Safety Code Sectional Committee
Ball Bearings Sectional Committee
Power Press Safety Codes
Bolt, Nut and Rivet Proportions Sectional Committee
Gears Sectional Committee
Screw Threads Sectional Committee
Insulated Wire and Cable Sectional Committee
Grinding Wheel Manufacturers Association
American Railway Electrical Engineers
Industrial Commission of Wisconsin
American Railway Engineering Association
International Association of Industrial Accident Boards and Commissions
American Society of Safety Engineers
National Aircraft Underwriters Association
American Gear Manufacturers Association
National Advisory Committee for Aeronautics
American Society of Mechanical Engineers
National Association of Mutual Casualty Companies
National Electric Light Association
National Machine Tool Builders Association
Underwriters' Laboratories
National Metal Trades Association
American Institute of Electrical Engineers
National Workmen's Compensation Service Bureau
National Safety Council
New Jersey Department of Labor
American Electric Railway Association
Pennsylvania Industrial Board
War Department
United States Public Health Service
National Fire Protection Association
Post Office Department
United States Department of Commerce (Bureau of Standards)
United States Forest Service
Association of Edison Illuminating Companies
American Bell Telephone Companies
Association of Sheet Metal Manufacturers
United States Coast Guard
Department of Labor and Industry of Massachusetts

FIG. 4—RELATION BETWEEN THE AMERICAN ENGINEERING STANDARDS COMMITTEE AND THE VARIOUS NATIONAL ENGINEERING ORGANIZATIONS

ciety, the chairmen thereof being designated by the President. Fig. 1 shows the administrative and special committees. The names of these committees, which report to the Council, indicate their duties.

A Nominating Committee of the Society is appointed each year and consists of one Member of the Society elected prior to the Annual Meeting from each Section of the Society and three Members of the Society elected at the Business Session of the Semi-Annual Meeting preceding the Annual Meeting at which officers are to be elected. No two of the three members elected at the Semi-Annual Meeting can reside in the same Section district.

Standards and Professional Committees

The Council appoints annually such standards or professional committees as are considered desirable to investigate and report on subjects of interest to the Society. The chairmen of such committees and their subdivisions are designated by the President. Fig. 2 shows the organization of these committees.

The Standards Committee is appointed to investigate, consider and report upon subjects the standardization of which will simplify and coordinate automobile engineering practices. The Committee consists of 26 Divisions with a total personnel of over 270. To facilitate the work Subdivisions are appointed consisting of members or non-members of the Standards Committee. Of the active Subdivisions appointed during 1921, 39 consist of more than one member and are shown in Fig. 3. The Subdivisions report to their respective Divisions, the Division reports having to meet with the approval of the Standards Committee as a whole before being submitted at Council and Society meetings. The work of the Standards Committee is carried on by the Standards Department of the Society under the Supervision of the Chairman of the Standards Committee and the General Manager of the Society.

A special committee, the members of which are also members of the Tractor Division, shown in Fig. 3 as the Special Committee of the Tractor Division, is appointed annually by the Council to cooperate with the American Society of Agricultural Engineers and the National Implement and Vehicle Association in the adoption of standards of interest to the three organizations. Standards approved by two of the three cooperating organizations become automatically "Agricultural Equipment Standards."

In addition, the Society, through the Standards Committee, is in touch with the following organizations in connection with standards matters of common interest.

Air Service, War Department
American Gear Manufacturers Association
American Petroleum Institute
American Society of Mechanical Engineers, Committee on Steel Roller Chains
American Society for Testing Materials, Subcommittee X on Automobile Steels of Committee A-1
Automobile Body Builders Association
Automotive Electric Association
Automotive Metal Wheel Association
Bureau of Construction and Repair, Navy Department
Bureau of Standards, Department of Commerce
Bureau of Steam Engineering, Navy Department
Electric Power Club
Forest Products Laboratory, Department of Agriculture
Gas Engine and Farm Power Association
Iowa State College
Lamp Standardization Exchange
Lock Washer Manufacturers Association
Motor and Accessory Manufacturers Association
Motor Transport Division, War Department
Naval Aircraft Factory, Navy Department
National Advisory Committee for Aeronautics
National Association of Engine and Boat Manufacturers
National Automobile Chamber of Commerce
National Electric Light Association
Ohio State University
Ordnance Department, War Department
Post Office Department
Purdue University
Rubber Association of America
Tire and Rim Association
Trailer Manufacturers Association
University of Nebraska
Wood Wheel Manufacturers Association

The Research Committee, consisting of 10 members, was appointed by the Council to supervise the analysis of the more important problems before the automotive industry and to obtain the necessary fundamental data to aid in solving them. The organization of a Research Department to carry on this work under the supervision of the Research Committee has been recently authorized by the Council.

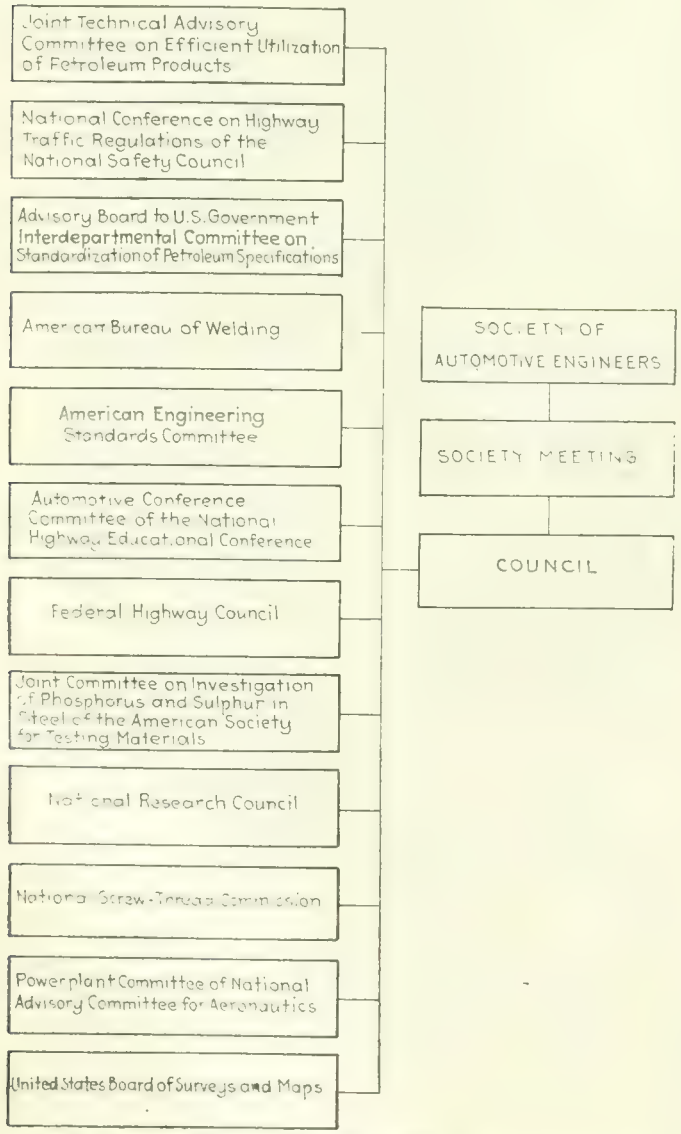

Joint Technical Advisory Committee on Efficient Utilization of Petroleum Products
National Conference on Highway Traffic Regulations of the National Safety Council
Advisory Board to U.S. Government Interdepartmental Committee on Standardization of Petroleum Specifications
American Bureau of Welding
American Engineering Standards Committee
Automotive Conference Committee of the National Highway Educational Conference
Federal Highway Council
Joint Committee on Investigation of Phosphorus and Sulphur in Steel of the American Society for Testing Materials
National Research Council
National Screw Thread Commission
Powerplant Committee of National Advisory Committee for Aeronautics
United States Board of Surveys and Maps
SOCIETY OF AUTOMOTIVE ENGINEERS
SOCIETY MEETING
COUNCIL

Fig. 2—Society Representation on National Organizations and Committees

The Automobile Insurance Schedule Committee was appointed by the Council in 1918 to cooperate in a technical advisory capacity with the Insurance Committee of the National Automobile Chamber of Commerce and the Underwriters Laboratories in formulating an improved method of establishing automobile insurance ratings based on the relative merits of mechanical constructions instead of the now discarded method based on prices. The Committee is also the arbitrating body for decision in disputed engineering matters pertaining to the schedule. There are nine members on this Committee.

The work of the Committee on the Science of Truck Operation which has five members is to compile truck operating statistics. The committee also keeps in close touch with the road impact-test work of the Bureau of Public Roads of the Department of Agriculture inasmuch as highway construction and maintenance are of vital importance.

The Patent Committee, consisting of three members, was recently organized to serve in an advisory capacity in standards matters involving patents.

The Tire and Rim Standardization Committee was established to determine upon a policy under which the Society will carry on tire and rim standardization in cooperation with The Rubber Association of America and the National Automobile Chamber of Commerce.

The Ordnance Advisory Committee cooperates with representatives of the Army in matters involving the design and operation of automotive equipment developed and used by the United States Ordnance Department. The present Committee has eight members.

American Engineering Standards Committee Sectional Committees

With the organization of the American Engineering Standards Committee the Society has become directly interested in 10 Sectional Committees appointed in accordance with the rules and regulations of the American Engineering Standards Committee. In four cases the Society is a sponsor for the Sectional Committee. Fig. 4 shows the different societies cooperating in the Sectional Committees of the American Engineering Standards Committee in which the Society is interested.

Representation on the Sectional Committees is indicated by the broken and full lines connecting the cooperating organizations with the Sectional Committees. Sponsorship, including procedure insofar as the approval of Sectional Committee Reports is concerned, is indicated by the full lines connecting the Sectional Committees with the cooperating organizations and those in turn with the American Engineering Standards Committee. It will be seen that many cooperating organizations are not members of the American Engineering Standards Committee, but merely represented on the Sectional Committees in which they are interested.

Society Representatives

The Society is represented by members appointed by the Council on several organizations of national importance, as indicated in Fig. 5. In this way the work of other national organizations of interest to the members is coordinated with the work of the Society.

DESIGN AND PRODUCTION

A CONSIDERABLE amount of attention has been devoted in recent times to the close connection that exists between design and production, but it is still very evident that this important relationship, while upheld by most engineers in theory, does not even now materialize sufficiently in practice. There are various reasons for this. Many products, for instance, involving expensive patterns, jigs, tools, etc., were originally designed at a time when the outlook on this subject was not so clear as it is at present. In other cases designs are put through, often of necessity, in such a way, and with such a time limit, that it is inevitable that production matters do not receive adequate attention. It is, however, important to urge the utmost possible consideration of all problems connected with manufacture in the early stages of the design.

Manufacturing considerations should commence with the very first layout on the drawing-board. It is not sufficient that the machine should be broadly schemed out first, and its manufacture considered in relation to the structure as thus conceived. It is scarcely necessary to point out that simplicity or complexity in production is settled just as much by the principles underlying the original layout as by the subsequent designing and arranging of details and dimensions. A careful survey of the design of almost any engineering product, whether this be of simple or complicated nature, inevitably leads to the conclusion that manufacturing methods have been planned inadequately in the original laying out of the design. This seems particularly unfortunate when it is borne in mind that modern machine-tools and manufacturing methods have now reached a stage where they offer to the well-versed and skillful designer opportunities of producing at an extraordinarily low cost; so much so, that even the cheapest materials in many articles of commerce, given a fair manufacturing design, will form the largest item in the total cost of production of the completed article.

In the case of other designs the production engineer labors in the face of tremendous difficulties. He is called upon to manufacture parts of unnecessary complication, involving expensive operations that have to be performed in an awkward manner, and is generally hampered in every possible way. Particularly glaring examples were, of course, furnished in the design of certain of the munitions used during the war, but here, of course, the urgency with which many of the designs were produced and the necessity for immediate output outweighted all other considerations.

Although bad design for production becomes, as a rule, most evident when the parts go into the machine-shop, and consideration for machining operations is of paramount importance, yet the pattern-shop, foundry and drop-forging or blacksmith's shop must not be overlooked in the drafting-room. Where this is a department of reasonable size dealing with a fair number of designs, it is evident that, until all draftsmen are equipped with the necessary knowledge of modern practice, somebody must be appointed capable of superintending the design of every detail part, solely from the manufacturing viewpoint. Before the drawing is issued it should be examined by the production expert, not only from the broad viewpoint of a part to be manufactured, but from the narrower outlook of a part to be manufactured by a particular factory, due consideration being given to the number required, the quality of workmanship and the plant available for performing the operations. Such an individual should have authority to reject unsuitable designs, and every effort should be made to render his work a valuable asset as a reducer of production costs. Superintended in this way, the design of practically any part or component can be modified in a way that results in considerable saving.—*Engineering Production* (London).

Education for Highway Transport

By Charles J. Tilden[1]

Semi-Annual Meeting Paper

THE author discusses the kind of college education that should be offered to those who expect to become engaged in highway transportation by motor truck, with reference to organization, regulation and operation on a large scale. Stating that the main factors of such an education fall naturally into the three divisions of the highway, the vehicle and the business, these are considered with regard to what topics might be presented profitably to college students under these respective heads, the subjects and the factors that govern their desirability being commented upon in general terms.

The main principle which should be borne in mind in educating men for the motor-transport business and the main value of such an education lie in the intellectual development and ability to analyze critically, which give the student mastery over new situations as they arise, and ready adaptability to the needs of any given business situation.

A GREAT business is being born. One of the oldest means of travel and transportation has come suddenly into the most prominent place in the Nation's economic life. With the increasing demand in the past few years for means of collection and distribution of commodities of all kinds the highway has suddenly taken a place fully as important as that of the railroad in this phase of human activity. The rapid development of the motor truck and the passenger car has, of course, made this possible, and our 2,500,000 miles of highways offer almost limitless possibilities for commercial development in the way of motor transport.

It is the business of schools to prepare future citizens to take their part in the organized work of the Nation. I have been asked to discuss the college education which should be offered to those who expect to engage in highway transport, with special emphasis upon the necessity of educating men who upon completion of their courses can organize, regulate and operate truck transport on a large scale. That is something of a task. It would be a very large order for any college or university. Suppose the Congress, in providing for the Military Academy at West Point, should instruct the superintendent to educate men who upon completion of the course would be in a position to take command of a brigade in the field and assume all the other duties and functions of a brigadier general.

The successful operation of truck transport on a large scale is no different from that of any other big business except that there is little or no past history or experience to serve as a guide. It calls for an unusual degree of initiative and foresight. It involves duties and responsibilities which can be performed only by men experienced in business organization and management, and experience is one thing which our colleges have not yet been able to teach. The college course does not aim to do more than fit men in the most efficient manner to begin their experience. The term "commencement," denoting the completion of the four years of college work, is used advisedly. It marks the real beginning of life's work, and a college man cannot be ready for inaugurating and carrying on a great business until his college work has been rounded out and tempered by some years of actual contact with business life.

What the Colleges Should Teach

There are, however, certain phases of instruction in the field of highway transport that can be offered profitably to the college student. They should be planned to put him in the way of study and thought along the lines of his expected life work. A well-rounded course which commands a large part of the student's time during his four years in college may well be based on the important functions of the highway in serving the community's transportation needs. Except in its strictly technical phases, such as highway location and construction, it is not necessary to limit this study to engineering schools. Students of business administration and other branches of the arts and sciences will find much in it of interest and profit.

In blocking out college courses in highway transport the main factors fall naturally into three principal divisions, the highway, the vehicle and the business. Let us consider these in order and see just what topics might profitably be presented to college students under the respective heads. The highway is such a universally accepted fact of life that we pay singularly little attention to it. It is, however, an objective fact which well repays study. It has an interesting history. It is based on fundamental laws of human needs and desires which bring out the community life in a most interesting manner. What the highway is, the relation it bears to the community and the individual, the laws under which it is established and maintained and the nature of the structure that is necessary to enable it to perform its functions properly are questions that cover a broad range in engineering, law and social science. The economic question of the cost of building roads and the best ways of financing this cost and providing for maintenance are also topics worthy of study by every citizen who must at some time or other vote on these questions. The regulation of traffic both in city streets and in other less congested highways is a science which in some of its phases is as exact as the demonstrations of Euclid, but has always the uncertain element of human action which adds greatly to its interest as a study. In this connection it may not be amiss to quote from a recent letter from the chief engineer of one of the large motor-car companies.

> When a man travels from his home to some nearby point and falls into a chuck-hole and breaks the spring or some other part of the car, he immediately gets in touch with the dealer or factory and tells what he thinks about the poor materials which they allow to enter into the car, but never thinks of calling up the road commissioner and complaining of the condition of the road. As a matter of fact, the average man does not know anything about roads. He probably would not know whom to call up if he wanted to complain about the road.

This situation has its basis, of course, in the fact that the car belongs to the individual. He has bought and paid for it and either loves or hates it, according to his frame of mind. The road, on the other hand, belongs to everybody, and hence to nobody. It is no particular con-

[1]Director, highway and highway transport education committee, Department of Agriculture, Washington.

cern to the car owner that there are holes in it, but it is of vital concern to him if anything happens to his car.

The prospective manager of a large highway-transport business should have an intimate knowledge of the motor car as an engineering unit. Here again there are many features of general interest that any well informed citizen might be expected to know. It is astonishing, in connection with the rapid increase of motor vehicles, both passenger and freight, how general the knowledge concerning them has become. School children who cannot pass history tests or do examples in the rule of three can discourse knowingly of spark-plugs, gasoline mileage and the relative value of different makes of car. The car, however, is an extremely complicated and intricate mechanism, a structure whose development has followed definite lines, and the difficulty of suggesting a college course on the subject would be to know where to stop and what to leave out. The fundamentals of the gas engine in both theory and practice should, of course, be thoroughly taught. The details of the construction and operation of different makes of car could be embodied in a laboratory course as exacting and with as high an educational value in mental training as any of the so-called pure sciences. One has only to think for a moment of what is under the hood to realize what wonderful exercises there are in dissection and synthetic coordination in the study of a motor truck. A considerable number of schools are now offering practical and theoretical courses in automotive engineering and this number might well be increased.

Instruction in the sound business principles which underlie all commercial operation is most important. In discussing the cause of failure of some recent motor-transport ventures a well-known operator in New York City wrote as follows:

> Motor-truck freight rates are based on the cost of truck operation and although over $2,000,000,000 is invested in motor trucks their operators are almost completely ignorant of their true operating cost.

This is from a man who has given considerable constructive study to the whole matter. It contains much food for thought on the part of those who are interested in the operation of motor vehicles as a business for legitimate profit. It should also be a challenge to our schools and colleges, for it points out where ignorance lies. Of course, all business is based on sound economics and fundamental courses in economics should constitute an important part of all business training. After this preliminary study, specialized courses could very well be offered dealing particularly with motor-vehicle problems. The difficulty with which we are confronted at once is the lack of reliable fundamental data. There is great need for research and for careful coordination and organization of existing facts with critical examination of the published material to determine how much of it really is fact. There is much more to the cost of operating a truck than simply the expense of gasoline and oil. The surface of the highway over which it must operate has a decided influence on operating costs. A prominent professor of economics in one of our large universities said recently that it would take five years to systematize and arrange the existing material in regard to highway transport so that a satisfactory undergraduate course of study could be developed from it. This is rather an appalling view to take, for long before the five years were up most of the material would be out-of-date.

The prime object of a college course is, however, not to give information, but to develop the student's thinking power and put him in the way of critical study of conditions as he finds them. There is probably not a college graduate of five years standing in the country who uses, to any great extent, merely the facts that he acquired in college. Mental power, intellectual development and ability to analyze critically constitute the main value of those four years. It does not matter so much what a student thinks about, or whether the material that he is studying is likely to be out-of-date in a short while, as long as he thinks straight, hard and continuously. Only in this way can he gain the mental power that will give him quick mastery over new situations as they arise, and ready adaptability to the needs of a business situation. This is, after all, the main principle that should be borne in mind in laying down a college course designed to train men for the motor-transport business.

But the college man must be first of all a citizen. He must understand the things I have indicated and many others in their relation to community needs. It is not well to give such a large proportion of the student's time to specialized subjects that the more general topics which enter into a broad education are sacrificed. A thorough appreciation of the fundamentals of history, training in expression, both written and spoken, some knowledge of at least one language other than his native tongue and an insight into the great fields of chemistry, biology, geology and physics, are part of the proper equipment of the educated useful citizen. He should be able to deal pleasantly and effectively with his fellow-men, understanding the principles of teamwork and cooperative effort. If he is able to get some of this on the football field he will have a training such as no course in the classroom can possibly give.

CORRECT ADDRESSES OF THE MEMBERS

A FORCE is maintained in the offices of the Society at New York City whose sole duty is to keep the addresses of the members uptodate. A large number of changes of addresses are received each week by this department, and these are made promptly. In numerous cases the only notification which the Society has of a change of a member's address is a letter stating that THE JOURNAL, or some other communication, either was delayed in delivery or was not received at all. It is, of course, impossible for the office to have a correct list of addresses unless the members send in such changes promptly. All members who are receiving mail addressed improperly are urged to send their correct address to the office.

A list of the members for which the Society has no correct address is given below. Communications sent to the last known business connection or mail address as it appears on the records have been returned to the New York office. Any one who can supply information regarding the present location of these members or offer any suggestions as to where their correct addresses can be obtained will confer a favor upon the Society by communicating with the Secretary at the New York office. It is only by the cooperation of the entire membership that a correct mailing list can be maintained and the members receive THE JOURNAL and other communications promptly.

ANDERSON, A. H.
BRADLEY, EDWIN PAUL
GREEN, L. P.
HAGELTHORNE, G.
JOHNSON, A.
MCNULTY, G. HAROLD
NORDEMAN, P.
TUCKER, GORDON E.
WILSON, CYRIL

Discussion of Papers at the Farm Power Meeting

THE discussion of the papers presented at the Farm Power Meeting of the Society, held at Columbus, Ohio, Feb. 10, included both written contributions submitted by members who were unable to be present and the remarks made at the meeting. In every case an effort has been made to have the authors of the papers reply to the discussion, both oral and written, and these comments, where received in time for publication, are included in the discussions. A brief abstract of each paper precedes the discussion, with a reference to the issue of THE JOURNAL in which the paper appeared, for the convenience of members who desire to refer to the complete text as originally printed and the illustrations that appeared in connection therewith.

THE CARBURETION OF ALCOHOL

BY A. W. SCARRATT

THE author describes the development of an alcohol-burning tractor engine, after having stated a few of the fundamental requirements for burning alcohol economically and the results that can be attained by following them. The first trials were with 127-lb. gage compression at a normal operating speed. The problems attacked were those of what amount of heat applied to the mixture is desirable and its general effect on economy, output and operation; power output; general operation of the engine; and fuel consumption. The experimental work was done on a 4¼ x 6-in. four-cylinder 16-valve engine; this is described in detail and the results are presented in chart form. The conditions necessary for the proper use of alcohol as a fuel are discussed. [Printed in the April, 1921, issue of THE JOURNAL.]

THE DISCUSSION

PROF. C. A. NORMAN:—There have been a considerable number of investigations regarding the possibility of using alcohol as a fuel for carbureting engines, and, with certain modifications of the engine, alcohol is a good fuel, giving a high thermal efficiency. The difficulty in America comes in supplying alcohol in quantities sufficient to play any important part in the automotive field and at prices low enough to make it competitive with other kinds of fuel.

In Germany large quantities of fuel alcohol are produced, mainly from potatoes. In this country we could do the same thing. We could also readily manufacture alcohol from corn. The yield might be about 2.70 gal. of alcohol per bu. of corn and about 0.75 gal. per bu. of potatoes. This would mean that about 5 to 10 per cent of the total farming acreage in this country, if cultivated with only moderate skill, would be enough to supply almost the whole automotive demand for fuel. It would not mean a revolution in agriculture. On the other hand, to produce alcohol salable at something like 50 cents per gal. or less, potatoes would have to sell for 15 cents per bu. and corn for about 50 cents. Such prices would not be very attractive to the farmer.

The possibility of manufacturing alcohol from farm waste products such as straw and cornstalks has long been thought of and some experiments have been conducted by the United States Government to determine what can be done in this line. So far it seems that the difficulties of commercial production of alcohol from these sources are very great, and perhaps the difficulties of collection and organization of the industry are as great as those of chemical conversion.

In Switzerland an extremely interesting process for manufacturing alcohol from coal by way of calcium carbide appears to have reached the commercial stage, the cost being surprisingly low. However, to supply the automotive fuel demand of this Country by this process, about 16,000,000 hp. would have to be applied continuously through the year. Our all-year waterpower amounts to only about 25,000,000 hp.

It seems that there is in America an almost unlimited source of fuel similar to the present-day petroleum fuel in the form of shale oil. In Colorado there is an estimated supply of 20,000,000,000 bbl. of shale oil in shale of fairly high yield. In southwestern Indiana there is a reserve of 100,000,000,000 bbl. in shale yielding about 10 gal. of oil per ton; even with such low yield it appears possible to produce automotive fuel at prices much below those at which alcohol could be produced. Judging from circulars of the Colorado School of Mines, some companies are now producing in the West shale oil on a commercial basis; some estimated figures given by apparently reputable and financially strong organizations, in California for instance, show a cost of production per barrel of shale oil lower than the present selling price of crude petroleum.

Nevertheless, alcohol as a fuel is of great interest in the foreign field, which at the present time is attracting more and more attention from American business, and for this reason as well as on account of the more or less special cases where alcohol can be used as a fuel of secondary importance in this Country, experiments and preparations such as those undertaken by Mr. Scarratt are of value. In this connection it may be of interest to recall the rather striking fact that the best all-round fuel mixture developed in Germany during the war consisted of benzol, alcohol and kerosene in equal proportions.

F. C. ZIESENHEIM:—Will Professor Norman give us some idea of the composition of shale oil?

PROFESSOR NORMAN:—The composition of shale oil in Colorado, as determined by Mr. Winchester of the Bureau of Mines, is somewhat similar to that of Pennsylvania crude oil. It seems desirable in view of the present fuel situation to develop an automotive engine capable of burning any kind of liquid fuel, non-volatile as well as volatile. If shale oil generally were of a composition

similar to that stated by Mr. Winchester, it would furnish a great quantity of fuel capable of being consumed in carbureting engines.

D. R. HARPER:—The process of producing alcohol from farm waste or any similar source is inefficient in so many ways that it is probable that a zero cost of raw material would not balance the losses inherent in the process. The primary process, namely, fermentation, is of a biological and not an engineering nature. We have virtually no control over its efficiency, and unfortunately it is a relatively ineffective process. Until the biologist knows much more about fermentation the engineer or alcohol technologist must remain content to take what nature gives him, which happens to be a rather weak liquor. Inasmuch as we start with a weak liquor, we must have distillation. The heat units necessarily consumed in this stage are so vastly many times more than we can expect to get back from alcohol as a fuel that there is an incentive to apply the distillation power source in some more efficient channel. Deep-seated natural reasons underlie the difficulties met by the alcohol production engineer; for example, inability to keep his plant busy long enough during the year to pay the interest charges. We cannot prod him to such great efficiency while the plant does work as to overcome the handicap of intermittent operation. The waterpower production method mentioned by Professor Norman is of interest as eliminating the biological factor and providing a process that is apparently more nearly under control.

D. L. ARNOLD:—We may not need to produce alcohol for engine fuel within our own lifetime but our children may have to produce it. When it is produced it will be a matter of by-products; alcohol alone will not be produced. The whole process must be taken into consideration in connection with the cost of producing alcohol.

An interesting method of getting power from straw and similar refuse products has been demonstrated in northern Canada. The trouble with the process is that no one has found a way to condense the gas that comes out of the straw. The heat value is there and some day somebody will find a way to do that. At present lampblack is obtained at the rate of about 400 to 600 lb. per ton. The price is 10 to 15 cents per lb. On a by-product basis the manufacture should not be too expensive.

F. F. CHANDLER:—With reference to Mr. Scarratt's experiments on alcohol, what did he find regarding so-called preignition?

A. W. SCARRATT:—There is absolutely no preignition.

CHAIRMAN E. A. JOHNSTON:—A prominent farmer near Chicago, who cultivates several thousand acres, suggested he would like to produce alcohol for power purposes from waste vegetable matter. I cooperated with him to some extent in looking up apparatus and the cost of production, but when we learned the details of the Government requirements covering the production of alcohol, we decided to give the matter up.

MR. SCARRATT:—I am optimistic regarding the fuel question. We have made very little use relatively of our knowledge of chemistry. We have ahead of us an enormous field in which we can be sure that the chemists will take a very active part within the near future. Within 5 years we will have revelations regarding fuel that will set aside all the anxiety we have at present.

CHAIRMAN JOHNSTON:—Under the present state of development the automotive engine, properly designed and constructed, will consume about 0.63 or 0.65 lb. of kerosene per hp-hr. and about 0.52 or 0.54 lb. of gasoline under favorable conditions.

Alcohol is fine fuel to use; one need not worry about the carbonization. It burns well; of course, it has some disadvantages, but this is true of every fuel we deal with.

NEBRASKA TRACTOR TESTS

BY OSCAR W. SJOGREN

BEFORE taking up the results of the tests, the author states briefly the provisions of the Nebraska tractor law, the kind of tests conducted and the equipment used.

Applications covering 103 different tractors were received during the season; of the 68 that appeared for test, 39 went through without making any changes and 29 made changes. The results of the tests are described and illustrated by charts.

The fuel consumption was studied from the three different angles of volumetric displacement, engine speed and the diameter of the cylinders, the tractors being classified accordingly and the results presented in charts which are analyzed. The weaknesses of the tractor as shown by the tests are commented upon at some length with a view to improvement of the product. [Printed in the May, 1921, issue of THE JOURNAL]

THE DISCUSSION

G. R. PENNINGTON:—The tractive force or total force exerted against the ground which a tractor can develop is a constant. The maximum available drawbar pull is equal to this tractive force less the force required to move the tractor itself and is therefore a variable depending upon soil conditions. In certain cases we are more interested in knowing the tractive force or tractive horsepower than the drawbar pull or drawbar horsepower available. A usual way to determine the maximum tractive horsepower is to measure the drawbar horsepower and add to that the power necessary to pull the tractor itself at the given speed. Have you tried that method?

PROF. O. W. SJOGREN:—No. We tried to test the tractors in the same way the farmer would use them.

A MEMBER:—The test sheet shows that the prevailing fuel was kerosene. It has been brought to the attention of many that there is a growing aversion to the use of kerosene as it is handled in the present carbureter system. What is Professor Sjogren's opinion as to the economic status of low-grade fuels?

PROFESSOR SJOGREN:—I do not know that I am in a position to give a definite answer to the question. The amount of gasoline used was practically the same as the amount of kerosene. We get practically as much horsepower from a gallon of kerosene as from a gallon of gasoline, provided the tractor is designed for kerosene.

MR. PENNINGTON:—Does the increase in crankcase oil dilution, which we get with lower-priced fuels, make up for the difference in price between kerosene and gasoline?

PROFESSOR SJOGREN:—I believe it does not.

PROF. W. T. MAGRUDER:—I would like to know why due allowance was not made for the power lost in transmission between the belt pulley and the dynamometer.

PROFESSOR SJOGREN:—Because we want to know what amount of power the farmer can take off; also because there was no definite rule for determining the loss without making a calibration of each machine. We discussed that for a long time before we arrived at our conclusion; we decided that, to be fair to everyone, the best method was to measure the power at the brake end.

PROFESSOR MAGRUDER:—Tests show that it makes a considerable difference how the power is taken off. For accurate results the dynamometer should be tested and the pull of the tractor on it standardized; otherwise results differing by 1 to 2 hp. will be obtained, which is a large percentage of the gross power.

CHAIRMAN E. A. JOHNSTON:—Most engineers appreciate the fact that belt power losses very considerably under different conditions of transmission. Unfortunately many manufacturers have not made sufficient allowance for belt clearance. The farmer is interested in the power delivered to the belt of the driven machine, as Professor Sjogren states.

D. L. ARNOLD:—To compare the performance of all tractors the maximum drawbar pull and the maximum belt horsepower, were reduced to a piston-displacement basis. On that basis I found that only two of the tractors tested fell below delivering 50 per cent of their belt power to the drawbar, while the tractors of highest efficiency came close to 82 per cent. Of course, that takes into consideration the friction of the transmission and driving mechanism to pull the tractor under load.

PROFESSOR SJOGREN:—That is probably due more to the condition of the track. We used a cinder track because we felt it could be maintained in a more uniform condition throughout the season than a dirt track, and because it was more like a stubble field.

H. W. RILEY:—Were the lugs uniform in every case?

PROFESSOR SJOGREN:—We made no specific point of investigating the equipment. We allowed the manufacturers to use what lugs they thought worked best; they investigated that and were in a better position than we were to make the proper choice.

MR. PENNINGTON:—In view of Mr. Arnold's statement, I wish to explain the reason for my question. If two tractors, which on the cinder track develop the same drawbar horsepower, were taken out in a soft field, one tractor might then deliver much more drawbar horsepower than the other, for the reason that less horsepower might be consumed in moving this tractor itself. The amount which a tractor sinks into the ground largely governs this factor. A comparison on a cinder track is not therefore sufficient for all purposes. We are interested also in knowing the power it takes to move the tractor over any given soil. I would like to ask whether Professor Sjogren has made any measurements of that kind.

PROFESSOR SJOGREN:—No.

J. A. SECOR:—I understand that the different kerosenes and gasolines used in the tractors varied considerably. Was any average quality determined for the kerosene and the gasoline as a whole that was used as fuel for all the tractors?

PROFESSOR SJOGREN:—The variation was very slight. We struck no average.

MR. SECOR:—The average would be about 6.75 lb. per gal. for ordinary kerosene, and 6.20 lb. for engine gasoline. These weights correspond with 43.2 deg. Baumé for the kerosene, and 58 deg. Baumé for the gasoline. Lighter or heavier kerosenes and gasolines should be within 1 per cent of these averages.

A. R. SANDT:—Did Mr. Sjogren determine whether the breakages were due to poor material or to faulty engineering?

PROFESSOR SJOGREN: — I think our report specifies whether there was poor material or poor engineering, and that it runs about half-and-half. Where the report said that considerable wear was noticed, I concluded what the main difficulty was. In one case where the flywheel flew to pieces, we concluded that we could not determine whether that was due to faulty engineering or faulty material. That happened when the operators were not present. The engine was started and seemed to accelerate very rapidly. It appeared that somebody had used a wrench on it. That merely goes to show that on a test one must be very cautious and watch every detail to get accurate results. When we made mistakes in our testing work, we tried to remedy them as soon as we noticed them. We did not get all the information we should have secured because of the pressure of the work. You can imagine what it means to have 103 tractors to test during a season, each one of which must be run from 20 to 50 hr.

A. W. SCARRATT:—Professor Sjogren mentioned the difficulty experienced with spark-plugs generally. I do not wish to defend the spark-plug manufacturers, but if the implement manufacturers will pay a little more attention to the design of their engines, with reference particularly to carburetion, lubrication and cooling, they will not have so much trouble with the spark-plugs. We have tested nearly every reputable make of spark-plug that is not of freakish design and of all of them there are about three that we can say do not stand up satisfactorily. This may not be the case with all engines. More attention should be paid to carburetion to make it thorough and complete; to the proper distribution of the lubricant, especially to prevent excessive lubrication; and to the timing. This will help to clear up much of the spark-plug trouble.

O. B. ZIMMERMAN:—We should extend a vote of thanks to the Board of the Tractor Test Committee of Nebraska for the extreme fairness and frankness with which they carried on this whole series of tests. They have been so generous in their courtesy that I am sure all of us will have gained much information from this analysis.

The questions have indicated that there are many things we would like to have incorporated in the analysis and undoubtedly they can be incorporated in the series of tests of next year. We would like to know what the relation actually is between the maximum drawbar pull of a tractor and its weight. That is, of course, obscured by lugs, wheel diameters and wheel widths. We should give much attention to lug and wheel data from an engineering standpoint. These factors constitute perhaps the weakest point in our general understanding of design considerations today. In traveling over the ground, we must look upon the whole tractor design from two standpoints, the effect of the weight and the effect of the lugs.

The plow itself should be designed to give a maximum disturbance of soil for a minimum expenditure of energy. The tractor itself, or the part which takes hold of the ground, should be designed with a contrary view, that of getting the minimum disturbance of soil and enabling us to transmit the greatest amount of power. In many of the tests which we are endeavoring to analyze, for instance, the relation of speed to draft, the actual data that interest us are covered up to a certain extent by the fact that altogether too often the soil is disturbed before the plow takes hold of it. That is particularly true when

we use the higher speeds. Inasmuch as all these data are taken at the drawbar, we must watch with care and not upset the analysis by believing that all of this work is done by the plow, when a good share is often done by a disturbance of the lugs, perhaps by a pressure which the engine carries to it and by narrow wheels. So, I think we should look into this matter of the design of wheels and lugs very carefully. We should also pay great attention to the transmission, the engine shaft and the rear axle.

In studying these Nebraska tests, I hope the analysis will include consideration of the enormous amount of power that is lost between the engine shaft and the drawbar. It seems almost foolish to lower the fuel consumption on the brake test and then lose in the transmission seven or eight times as much as seems necessary. I think that will show that we have given excessive attention to the engines. It will be found that many engines give excellent fuel consumption in relation to the power delivered at the engine shaft, but are excelled by many other engines when the power is measured at the drawbar. I hope we will soon analyze the power losses in the bearings and the gearing and those due to wheel design and the like.

PROFESSOR MAGRUDER:—In comparing with the drawbar horsepower the horsepower delivered at rated load for 2 hr., I find that the drawbar horsepower per gallon varies from 33 to 82 per cent of the actual horsepower at the pulley. I suggest that the Research Committee investigate why we lose this large amount of power in transmission.

MR. SANDT:—Did Professor Sjogren notice any particular difference between the various types of final drive?

PROFESSOR SJOGREN:—I will ask you to take the tabulated reports and draw your own conclusions.

A MEMBER:—I suggest that, if possible, during the next series of tests, standardized belts that are suitable for the pulley widths be used, and that the slippage on different diameters of pulley be obtained.

PROFESSOR SJOGREN:—The belt slippage was given for each test in the official reports. We shall be glad to receive suggestions from the Society as to items that should be included in our next report. We expect the coming season to be fully as strenuous as the last one was. We have had 20 requests for tests and that is about the same number we had last year at this time.

H. W. SIMPSON:—Why are some of the tractors ratings omitted?

PROFESSOR SJOGREN:—Because the firms make no rating. The ratings shown on the chart are the manufacturers' ratings.

E. R. NASH:—Why are some of the lug data left out?

PROFESSOR SJOGREN:—Where lug data are not given, the tractors were of the crawler type, no lugs being used.

R. I. SCHONITZER:—Did the test include a record of the results obtained with different types of bearing, such as plain, ball and roller, as used in engines and transmissions of the various tractors tested. Were the results obtained with different types of lubrication system included?

PROFESSOR SJOGREN:—No, but we will be glad to include additional interesting features in future tests if the members of the Society will make suggestions.

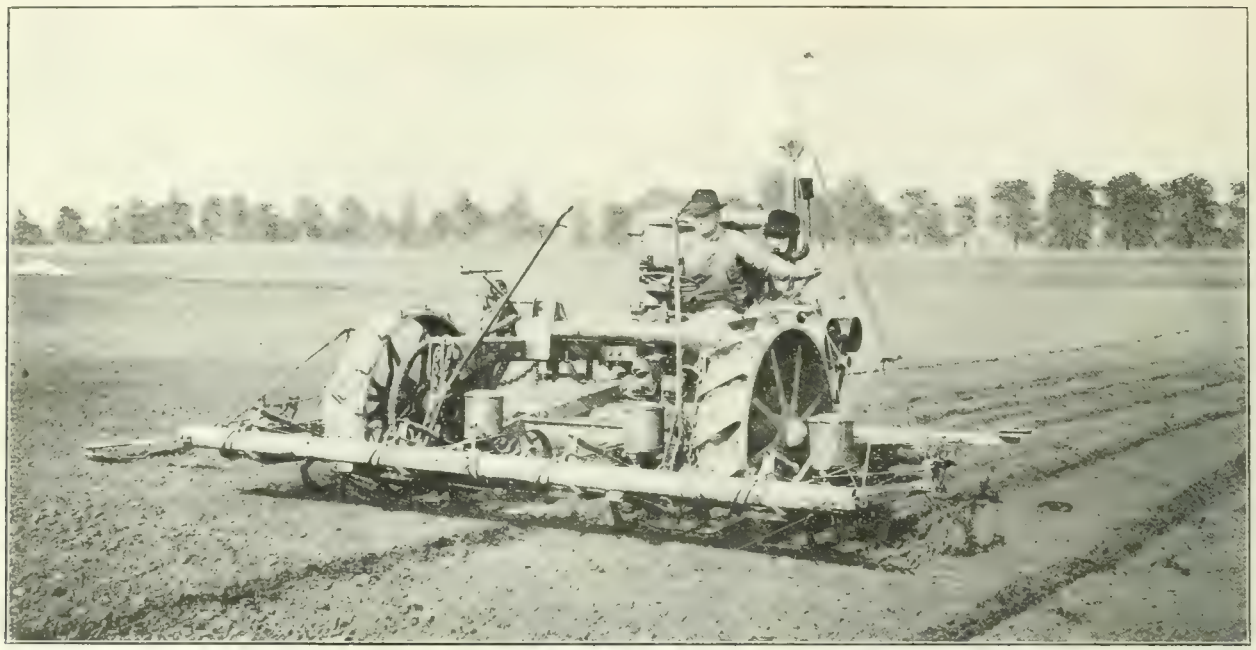
CHAIRMAN JOHNSTON:—The tractor industry will succeed in direct proportion to our ability to make tractor operation profitable to the tractor user. This should control the trend of tractor design. In the early days it was a question whether tractors should have two, three or four wheels, or have a track. The problem, as I see it, is one of designing the tractor for greater reliability, durability and economy, and developing the usefulness of the tractor to the greatest possible extent. The tractor operator is not an engineer and cannot be expected to make frequent adjustments and replacements. The successful tractor will be designed so that it will require a minimum amount of attention other than supplying fuel, lubricant and water once or twice daily. Gear, sprocket, shaft bearing and other pressures and stresses will be kept low enough to insure durability and eliminate breakage. Obviously, only material of the highest grade should enter into the construction of the modern tractor. The economic use of fuel and lubricants and convenience of operation are important factors.

THE FUTURE TRACTOR

The future tractor should be provided with a take-off to transmit power to binders and other implements. On most farms, diversified farming is carried on to such an extent that power must be applied to many implements that cannot be operated profitably with tractors designed for heavy drawbar and belt work only. The farmer's problem is one of production and the cost of production. As the cost of labor averages 40 to 50 per cent of the total cost of production, it is clear that the production per man must be increased to decrease the cost of production. This is an engineering problem and can be solved by the proper application of automotive power to agricultural equipment. I will not attempt to say how it can be best accomplished, but will present some recent developments that have a bearing on the solution of the very important problem of the application of automotive power to agricultural equipment.

This power machine is designed with two drivers, and can be operated in either direction. The plows can be attached and detached conveniently and quickly. The operator's seat is rather high, but he is up out of the dust. That is one of the advantages. One of the drive-wheels operates in the furrow, which is beneficial under

A POWER-DRAWN TWO-PLOW OUTFIT



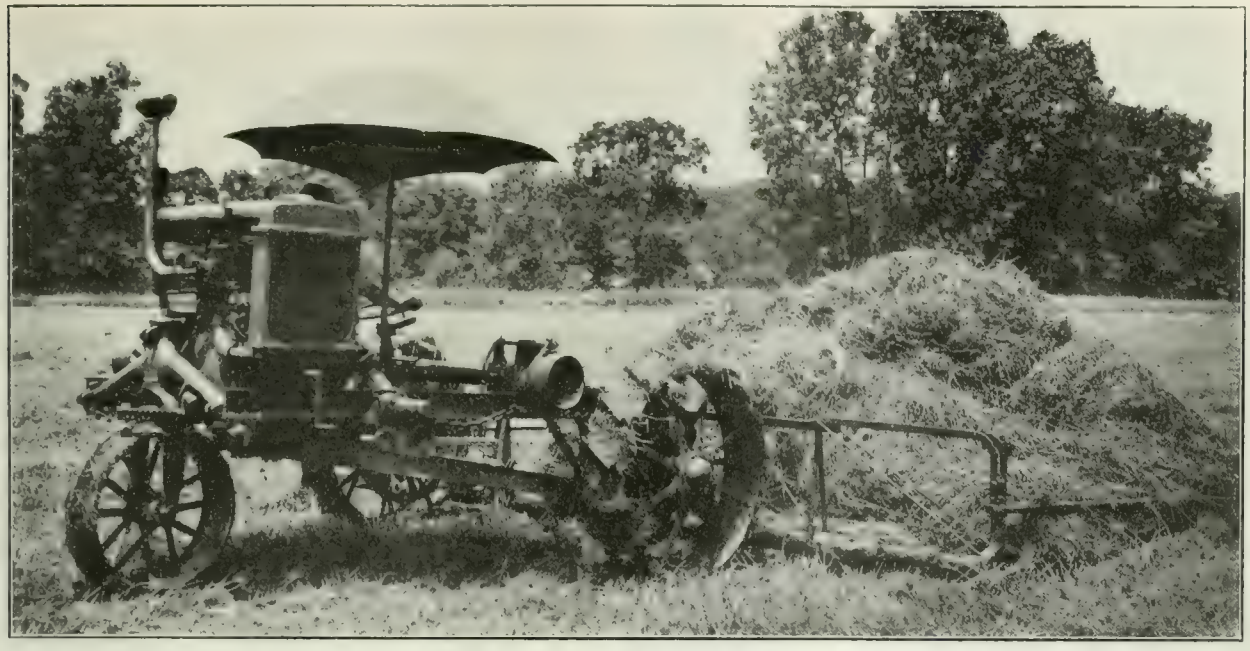
A Four-Row Corn Planter

some conditions, in fact, under most conditions. The same tractor operates a four-row corn-planter, planting about 2½ times as much acreage per man as the ordinary two-row horse-drawn planter. The four-row planter weighs and costs slightly more than the two-row planter and can be attached and detached quickly and conveniently. It is designed to turn short. The power-operated cultivator can be attached and detached quickly and guided quickly with very slight effort by the operator. This cultivator costs about 75 per cent as much as the horse-drawn cultivator and cultivates two rows at a time.

A power-operated mower has a 14-ft. cut, twice the width of cut of the horse-drawn mower. The mower in this case costs just about the same as the 6 or 7-ft.-cut horse-drawn mower. One operator can mow hay at the rate of 4 acres per hr., which is about three to four times the capacity per man with a team. The bars are raised quickly and automatically. Besides, there is a hay-rack with a capacity of 12 to 14 ft., increasing the capacity per man 300 to 400 per cent. All of these implements can be attached conveniently and quickly without the use of any tools or removing any bolts.

A wide power-driven sweep-rake and grain-shock gatherer can be folded up for passage through fence gates, and unfolded for operation afterward. It has a large capacity as a sweep-rake, and the same implement when

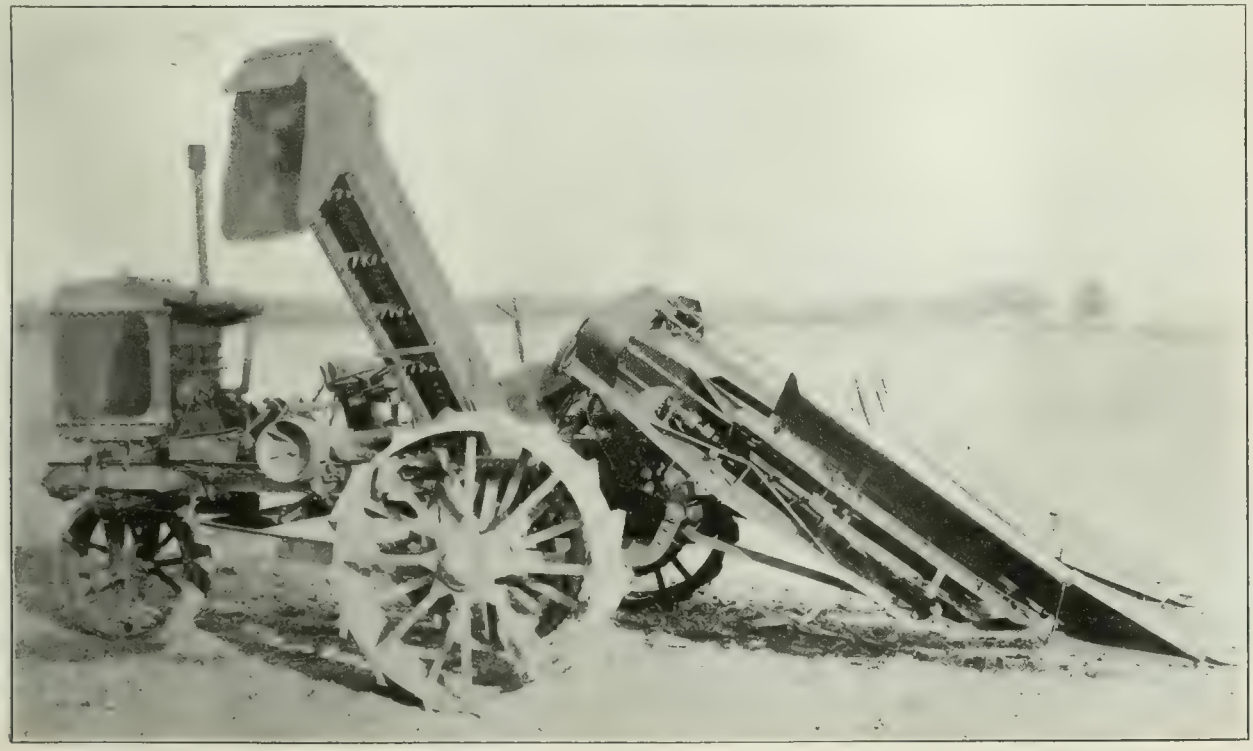
The Two Bar Mowing Machine



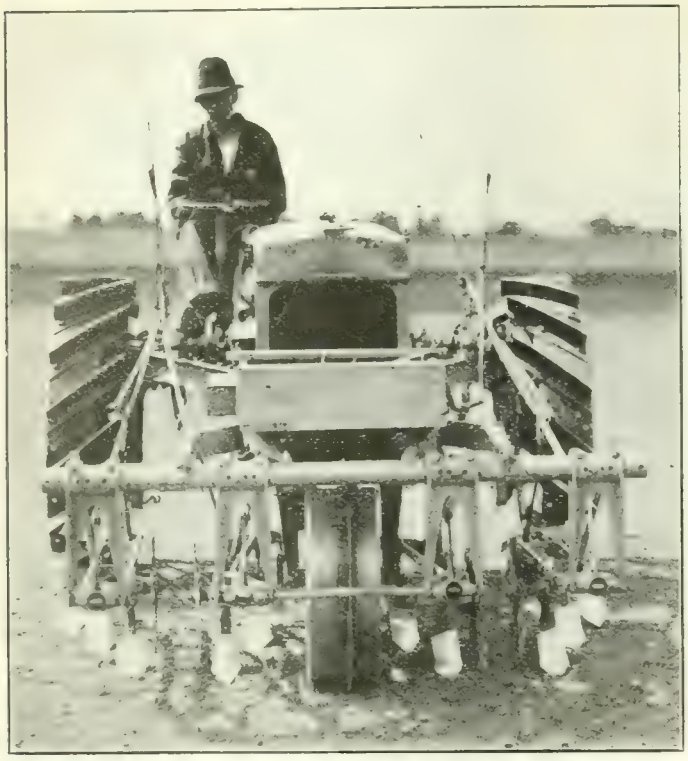
THE SWEEP RAKE AND SHOCK GATHERER

gathering shocks has a capacity of from 8 to 12 grain-shocks. It gathers the shocks without shelling the grain as badly as when pitched by hand. It has a capacity sufficient to enable one operator to keep a small separator fully supplied. With it a man can do the same work that ordinarily three teams and six men accomplish. There is much lifting to be done on all farms. A power-operated derrick has been adapted to this same machine to handle hay or do other lifting such as loading corn stalks out of the field and onto the wagon. It is often desirable to remove the corn-shocks to enable the farmer to plow. Corn-shocks are very difficult to handle by hand.

The 10-ft. binder and harvester weighs and costs approximately 60 per cent as much as the conventional horse-drawn machine; it can be equipped with an automatic shocker. The same machine handles a grain-header that has an 18-ft. cut. The header weighs and costs slightly more than half as much as the regular horse-drawn implement. It has the advantage of opening up a field without tracking down the grain. This machine is an adaptation of a horse-drawn corn-picker, which weighs less than 2000 lb. as designed for use in connection with the power machine. Its operation is very much improved by maintaining a uniform motion. There is also a



A TRACTOR-OPERATED TWO-ROW CORN PICKER



THE TWO-ROW CULTIVATOR

tractor-operated two-row snapper, which picks the ears from the stalks without husking them.

With all these machines the power is transmitted directly from the engine to the machine, which is a great advantage in operation. Regardless of the movement of the machine forward, it operates at uniform speed, which results in a high grade of work.

PRESIDENT DAVID BEECROFT:—This session has given us a fine insight into the wonderful chapter of farm power. The adaptation of power to the farm has been very different from the use of power in the factory. In a large factory we have a centralized powerplant, and the power is conveyed from it to the different departments. What would we think of a factory that had a separate powerplant for operating each department? But, literally, that is what we have had on the farm. On a relatively small farm in Minnesota one man had two tractors, two motor trucks, two automobiles, one house-lighting equipment and six stationary gas engines of different size. Mr. Johnston has illustrated the modern thought of the unit powerplant that serves all the purposes.

F. F. CHANDLER:—Or how small a farm would it be possible to use a combined equipment economically?

CHAIRMAN JOHNSTON:—It all hinges on the cost of operation. Much has been said about the cost of horse operation and it can be elaborated on to an enormous degree. To keep a horse requires the product of five acres, according to the best information available. The feed is about 60 per cent of the cost of keeping a horse, so that the value of the product required to supply the other 40 per cent means that a total of about 8 acres is required to keep a horse. It is possible, as I see it, to develop power-driven farm equipment along the lines mentioned or along some other line so that machines will replace all of the horses on the average farm of 100 to 150 acres. Usually about seven to ten horses are kept on a 150-acre farm. If there were only six or seven horses and the value of the product of eight acres is taken for each of those horses and the result compared with the cost of a power combination equipment, it will be found that the power equipment can be operated at approximately 60 per cent of the cost of operating by horses. Ultimately, of course, the cost of operation and of production will determine the answer.

MR. CHANDLER:—That possibly answers the question as far as it can be answered at present. What I had in mind is how small a farm it is possible to operate with a tractor and combined power-driven implements; for instance, if all of the combined cost due to horse equipment were applied to power-operated implements, how would that combined value of the horse equipment compare with the combined cost of the machinery that is desired to replace it?

CHAIRMAN JOHNSTON:—One of the great advantages to be obtained by some such development is the reduction in the weight and cost of implements. The power-driven implements will cost from 40 to 75 per cent less than horse-drawn implements of equal capacity. Perhaps I can answer the question by saying that the tractor for heavy belt and drawbar work is being developed rapidly. It has been developed to a point where there is no question as to its usefulness or as to its being a profitable investment for a farmer who tills 75 acres or more. Obviously, to reach the small farms, some such development as I have described must be accomplished because, if the small farmer carrying on diversified farming can use his tractor only for drawbar and belt work, he can make profitable use of the tractor for only approximately six to eight weeks in the entire year and it will be necessary for him to keep approximately the same number of horses as before to handle his row crops, which could not be handled to advantage with a tractor developed for drawbar and belt work only. Summing the matter up, as nearly as I am able to determine, a properly developed combination outfit can be used profitably on farms of 50 acres or even less.

FRED C. ZIESENHEIM:—A farmer in Pennsylvania kept an account of the number of horse-hours used per year. He determined that the maximum number occurred in the cultivation and not in the plowing season. Nevertheless he bought a tractor for use in the plowing season, because he gained time; he gained one month last year. He was compelled, however, to keep his horses to take care of cultivation and emergencies.

MR. PENNINGTON:—Why are implements designed to be used with tractors cheaper than those intended to be pulled by horses? It seems offhand that horse-drawn implements would be cheaper since they are pulled at lower speed and can therefore be made of lighter construction.

CHAIRMAN JOHNSTON:—On all machines designed to be pulled by horses, the power is transmitted from a ground wheel into the machine through a transmission mechanism. The weight and cost of the carrying wheels, the transmission mechanism and the construction necessary to carry that mechanism are eliminated in the implement designed to be operated by power along the lines I have described.

C. A. ATHERTON:—What are the possibilities of operating tractors at night, and the probability of equipping all tractors with electric lights as standard parts?

CHAIRMAN JOHNSTON:—That is a very interesting question. When we commenced to sell tractors 10 or 15 years ago, there was a demand for lighting equipment in the Dakotas and the prairie country. Night tractor operation was carried on to a considerable extent. In a

general way the operation of tractors at night results in just the same expensive unsatisfactory operation as night work in a factory, excessive breakage and higher cost of operation per unit of work. Furthermore, there are many farming operations which cannot be done to advantage at night on account of dew and other conditions. While there is some demand for lighting equipment to operate tractors at night, it has not been sufficient to justify supplying it as standard equipment.

MR. ATHERTON:—I am not a farmer or an agricultural engineer. I am looking at the subject from an illumination point of view. It seems to me that the farmer has less choice as to when he shall work than has an operator in any of the other industries. He is more dependent upon the seasons and must work when conditions are right. It is necessary frequently for him to put in 24 hr. of work at the right time. In a late spring the farmer might have to crowd all his plowing into one-half the time that he would ordinarily devote to it.

CHAIRMAN JOHNSTON:—Your thoughts along that line are correct but in practice they must be modified. The small farmer may have one man to help him or a man and a boy or two boys. He cannot operate 24 hr. without additional help. It has been difficult to get help of any kind. On the larger farms the equipment is generally adequate to perform the farm operations at the most desirable time. There is very little demand for tractor lighting equipment at this time.

MR. SANDT:—Is there any demand for starting apparatus?

CHAIRMAN JOHNSTON:—There is always a demand for starting apparatus or any convenience on a tractor, the same as for any other device or machine. The conventional starting device operated electrically and requiring a storage battery has not been developed to a point where it can be used generally on tractors; at least that is the attitude of most tractor designers. Starting equipment is standard on some tractors, and seems to be very satisfactory; but, in a general way, I believe that tractor development is not at a stage where it should be complicated with electric starting apparatus.

MR. NASH:—On the large farms in California and along the Pacific coast it is the practice to use the tractors at night to a great extent, and electric lighting is largely used there. A few tractors are equipped with gas light, but the most satisfactory equipment appears to be a generator of approximately constant voltage driven as seems best and operating without the use of a storage battery. One of the manufacturers brought out a gear drive for one of these generators which no doubt will prove much more satisfactory. Our most successful owners, during their plowing and seeding season or in doing discing or anything of that kind, operate 22 hr. daily for six days. On the seventh day they lay up and go over the rigs. They will not stop during the week except for an emergency.

COMING AERONAUTICAL DEVELOPMENTS

IN spite of the depressing conditions under which the aeronautical industry is laboring the technical development of the flying machine is not by any means being neglected. On the contrary, experimental and research work of a bold and ambitious nature is being actively prosecuted in many quarters. Ideas are changing and advancing rapidly, almost if not actually as rapidly as they did in the war period. During hostilities the progress made was great outwardly, but, in point of fact, it was very largely indeed composed of a refinement of detail, a growth in the absolute size of machines, and a development of the country's capacity to build them, their engines and accessories. Of genuine technical evolution, the war period showed much less than is ordinarily supposed. The airplanes at the end of it, with one or two exceptions, were substantially the machines of 1914 with increased performance and added powers. None of the belligerents could afford to spend much time developing radically new and untried ideas. The progress effected was truly remarkable, but it was practically all made within the lines of the earliest machines to take the field. Today, with the leisure enforced by the dullness of constructional activity, the country's aeronautical designers and research workers are exploring fields that, although visible during the war, were by force of circumstances all but forbidden to them. The evolutionary tendencies in play at the present moment are powerful and widespread, and if the industry can be granted survival for a space, they will almost certainly result in the near future in practical developments, besides which the progress made during the war will assume considerably less importance than we have been accustomed to accord to it in the past.

Let aerial transport, whether by flying machines or dirigible airships, attain an equal degree of safety, economy and trustworthiness to that of the railroad and the steamship, and it will be impossible for the public to avoid accepting it as a part of its daily life.—*The Engineer* (London).

DIESEL ENGINE SIZE

THE reciprocating steam engines of the steamship *Olympic* have cylinders of 4000 hp. each, so that a single four-cylinder engine develops 16,000 hp. A Diesel engine developing only 250 hp. per cylinder would, of course, require 64 cylinders to give the same power. The enormous multiplicity of parts to be looked after and kept in adjustment, even if this were individually easy, would be sufficient to prevent such use, while, in fact, the Diesel engine requires unusual care and attention to keep it in good order.

The question naturally arises, "Why is it that the Diesel engine cannot be built in large sizes?" Like all other internal-combustion engines, the Diesel engine requires that the cylinders be water-jacketed to keep the barrel sufficiently cool to permit the proper working of the pistons. The pressures carried are high, from 700 to 1000 lb. per sq. in. requiring a thick cylinder even for a power of 250 to 300 hp. The fact is this thickness is evidently about the maximum that will permit the interior cylinder wall to be kept of a sufficiently low temperature for satisfactory working. It happens that cast iron is by far the best material that has ever been found for the cylinders of quick-moving reciprocating engines. If a material having all the fine wearing qualities of cast iron with several times its thermal conductivity could be found, we might expect Diesel engine cylinders of greater power; but until that comes, or there is some other radical invention, the nature of which is not now evident, the Diesel engine seems limited to small powers.—W. M. McFarland in *American Machinist.*

PROFESSIONAL ENGINEERING EDUCATION

FOR some reason members of the principal engineering societies and associations of this country are deeply dissatisfied with their professional status, as indicated by the failure of the public, as they claim, to give the members of the profession proper consideration in their professional work. There have been many meetings, joint and individual, of these societies and associations, for the purpose of discussing this failure to receive sufficient professional recognition from the community at large. New organizations have been created recently to secure better professional recognition.

A great majority of our engineering schools are called "colleges of engineering." Obviously the mere name of an educational institution is of subordinate consequence. In the present instance, however, calling a professional school an "engineering college" makes a course of study that ought to be thoroughly professional in character merely a scientific college course, and that is the fatal defect of a great majority of the engineering schools. They are neither professional schools nor are they in reality colleges. They are a kind of hybrid that produces neither the broadly educated college man nor the educationally trained professional man. Some of them have served well a transition purpose, but the type is far from that of a professional school.

More than 70 years ago the oldest engineering school in America, Rensselaer Polytechnic Institute, reorganized its professional course of study with a vision as to the future both wise and remarkable. It sought to establish a professional school of engineering and applied sciences by formulating a course of wholly professional study of three years' duration to which college graduates were invited to come for their professional engineering training. It was fully 50 years in advance of the time when such an effort could possibly succeed. The experiences of the first year of this course of professional study showed that it then had no prospect whatever of success. To remedy the difficulty a preparatory year of study was formulated so that non-college graduates could thus prepare to begin the three-year course of professional educational work, making four years in all. This was the origin of the prevailing four-year course of engineering study which has become general throughout the United States. It would appear that the idea of basing professional engineering educational training on a broad general schedule of study such as that afforded by the usual college course has somehow dropped out of all consideration whatever, except in a few rare cases. There is distinctly a feeling that something needful is not included in the present engineering courses, even in the mind of those who administer and defend them, and their apprehension is too well founded. There is something of the utmost importance lacking. Both students and instructors of those institutions yield, although unconsciously, incontrovertible evidence of that fact.

Comparison With Law and Medicine

I am well aware that many engineering instructors and practicing engineers who are interested in engineering education argue that the engineering profession is in some way so different from the learned professions of the law and medicine that the general type of educational training which they have adopted for entrance into those professions is not suitable for the educational training of young engineers. They now require in their best professional schools a broad general education acquired in the college on which to base the professional educational training. Anyone who is observant enough will find that a large proportion, and probably the majority, of those two professions who have reached the beginning of middle life are men, broadly speaking, not only of technical ability and excellence but also possessing what may be termed, in the broad sense cultivation. They can take their places with credit to themselves in any place in the community where they may be called. They possess individuality and those qualities of mind and character that demand and receive public recognition both in and out of their professions. It is not necessary to enlarge upon the lack of such acknowledged position in the community on the part of engineers, for they themselves have set it forth within the past few years in clear and unmistakable terms. All curative efforts made through engineering organizations, are bound to fail in large part as they have failed up to the present time, unless one fundamental condition is first fulfilled and that is, the engineer must have a full professional education as a basis for his professional career before he can properly demand or be accorded by the public, full professional standing. Indeed, if it were feasible to give every engineer in the country a suitable professional educational training the profession would in a short time attain to the high position that it covets and be accorded by the public, full professional standing. Indeed, striving to attain, without any other aid whatever, just as the professions of law and medicine have done.

The high position and the great advantages reached by any profession are actually due to the acknowledged character and attainments of a majority whose capacity and character make them marked individuals and whose prestige gives standing to the entire profession.

Introducing Six-Year Course

The four-year course of engineering study has served a purpose and served it well, but I believe it can be stated without being effectively controverted that by far the best results have been reached where the course of engineering study has been based upon the broad course of general educational training given by colleges. I know that the usual standard objection will be made that there are few young men in the community who have sufficient time and means to take seven or eight years for such a course of study. In the first place it can be flatly stated that young candidates for law and medicine find it feasible to devote sufficient time for the desired purpose and I know of no reason why young candidates for the engineering profession cannot do the same thing if they have sufficient virility, resolution and, I hesitate to say, intelligence. In the second place, I can state from personal knowledge and experience that seven or eight years is not required. Six years is ample, three years in the college and three years in the engineering school. If our secondary schools were administered a little more intelligently it would be not only perfectly feasible but easy, as it has been in many cases, to give a young man this six-year engineering course of study and graduate him ready to begin his active practice at 22 years of age, which is a less age than that at which many and perhaps a majority of young men graduate from the standard four-year engineering course.

In the case of the four-year course, the student not having had any prior general education at a college or elsewhere, it is probably wise to introduce as much English instruction during the first year as is practicable. A similar observation can properly be made in reference to one prominent modern language such as French or Spanish. Such general cultural subjects, however, should be limited to the first four years, and as soon as the required development permits the installation of a prior general education in a college of cultural or liberal arts work these subjects should be confined to that part of the educational training, leaving to the professional school the entire time set apart for technical work. Doubtless in some or even many localities it might take a considerable period of years to reach the full professional educational training consisting of a broad general education of not less than three years, leading to the professional school having a course not less than three years in length, but that is the end toward which all possible efforts should be directed. College courses taking no more than three years' time are now common.

It is no exaggeration to state that the hope of the future of the engineering profession in this country lies in the development of a proper professional engineering education which with exceedingly few exceptions has not yet been attained. The position of the legal and medical professions points the way with absolute clearness. The engineer must be made a

man of cultivation as well as of technical excellence. In order that he can become the most useful citizen possible he must combine with his rather narrowing technical excellence those qualities which give him character and standing an an individual qualified to win the esteem and respect of those about him for his executive capacity wherever he is found to possess the executive quality. In other words, he must be a man entitled to receive the confidence of the community in which he practises.—W. H. Burr, before the Society for the Promotion of Engineering Education.

SUBSTITUTES FOR ASH IN AUTOMOBILE BODIES

ASH has always been considered the most desirable wood for use in automobile bodies. It combines the properties of moderate weight, easy workability, high degree of toughness and comparative freedom from warping. On account of the high price of ash, however, other woods are gradually replacing it in all but the most expensive cars. Some of the advantages and disadvantages of the substitute woods as compared with forest-grown ash for automobile construction are presented in a description that has been prepared by the Forest Products Laboratory, Madison, Wis.

Hard maple is used for sills in many cars, and in some for the framework of the body and the floor and running-boards. Maple is fully as strong and stiff as white ash, but is not as shock-resistant. It is usually cheaper than ash and runs more uniform in strength. Maple warps very little, in this respect being superior to elm, but is more difficult to season without checking than ash or elm and does not hold screws so well. On account of the smooth, fine texture of maple, paint and enamel rub off it easily, especially on curved surfaces that receive considerable wear. Because of its smooth-wearing qualities and comparative freedom from slivers, maple is preferred to all other woods for the floors of delivery trucks and other vehicles carrying freight.

Elm is principally used for frames, seat backs and doors; very little, if any, is used for sills. White elm is preferred to rock elm, except for some of the bent parts, because it is more easily worked and is less subject to warping. For the same reasons lumber from old white elm trees, usually called gray elm, is preferred to that from younger trees. Old white elm is not so strong or tough as ash, on the average, but it varies less in strength.

Yellow birch is a close rival of maple. It is used for sills, framework and many minor parts and is said to hold the paint better than maple on exposed surfaces.

The true hickories are used almost exclusively for spokes and felloes. The pecan hickories, which are somewhat inferior as a class to the true hickories, might be used in body construction, although their hardness and tendency to twist would perhaps prove a serious fault.

Red gum is too weak and soft for the sills and other major parts of the body frame, but is used for floor-boards, seat risers and other minor parts. One of the principal disadvantages of gum is its tendency to warp with changes in the moisture content. Quarter-sawed gum gives less trouble from warping than plain-sawed gum.

In automobile construction no distinction is made, as a rule, between the different species of oak or even between the red oak and white oak groups. In truck bodies, oak is one of the leading woods, being used for sills, cross sills, frames, floors and stakes. Oak is rarely employed for the frame or sills of passenger-car bodies. Wormy oak is used for running-boards, floor-boards and seats, and some sound oak is used for instrument boards and battery boxes. Top bows are made almost exclusively of oak, second growth being preferred.

Longleaf, loblolly, shortleaf and some of the minor Southern pines have been found adaptable for running-boards, floor-boards, seat-boards and a number of small parts in the seats and frames.

Cottonwood is used for the dash of passenger cars and the boxes or bodies of trucks. Sycamore, beech, basswood, yellow poplar, cucumber, tupelo, gum, chestnut, Douglas fir and Western yellow pine have also entered into car body construction to a small extent.

The four physical properties most important in automobile construction are given for each of the different species in the accompanying table, the strength of forest-grown white ash being taken as 100. Actual strength values of these species are to be found in Department of Agriculture Bulletin No. 556, entitled Mechanical Properties of Woods Grown in the United States.

STRENGTH OF WOODS USED IN AUTOMOBILE CONSTRUCTION IN PER CENT OF THE STRENGTH OF FOREST GROWN WHITE ASH

Species	Strength as a Beam or Post	Stiffness	Shock Resisting Ability	Hardness
Hardwoods				
Ash, white, forest grown	100.0	100.0	100.0	100.0
Ash, black	71.3	79.3	90.1	62.3
Ash, white, second growth	122.5	117.6	119.6	118.9
Basswood	59.1	80.6	40.5	29.6
Beech	93.5	96.9	96.0	90.0
Birch, yellow	104.8	116.8	120.6	80.9
Chestnut	66.0	71.9	53.4	49.2
Cottonwood	60.6	79.0	54.3	35.3
Cucumber	85.4	112.4	76.7	54.9
Elm, rock or cork	98.8	92.9	140.5	101.6
Elm, white	79.2	79.5	89.5	57.1
Gum, red	80.7	91.5	75.5	59.0
Gum, tupelo or cotton	81.4	82.5	63.5	77.3
Hickories, pecan	103.5	103.8	119.7	139.6
Hickories, true	126.6	120.2	173.9	150.4
Maple, red	90.0	101.2	78.7	75.4
Maple, silver	66.9	68.5	71.7	64.3
Maple, sugar	104.7	105.9	90.5	103.0
Oaks, all kinds	92.6	101.3	94.9	104.5
Poplar, yellow	67.3	93.8	41.5	37.9
Conifers				
Fir, Douglas, Pacific Coast	95.7	122.1	59.9	58.3
Pine, loblolly	93.7	105.6	71.0	60.0
Pine, longleaf	112.2	122.1	77.7	74.8
Pine, shortleaf	94.1	100.6	69.7	64.0
Pine, Western white	75.5	99.7	53.8	37.0
Pine, Western yellow	67.0	75.6	42.9	41.0
Spruce, Sitka	69.5	94.1	63.3	44.9

NEW TYPE OF AIRPLANE PROPELLER

AN Englishman by the name of Bourke has invented a new type of propeller, which, it is claimed, will go a long way in lessening the noise and vibration caused by the existing type of airplane propeller. It is claimed by the inventor that his propeller by attaining the maximum thrust will increase the speed and at the same time require less engine power. Instead of being smooth, the blades of the propeller have a number of flanges made of aluminum raised about 6 in., which run in parallel lines across the surface and work just as the teeth of a turbine. With the new propeller the wash of the wind from the blades drives in a steady flow instead of striking the planes and struts in whirling gusts thereby increasing vibration. The grip of the serrated blades in the air is much greater and therefore a much higher speed is obtained in taking off. It is understood that the Handley-Page company contemplates making exhaustive tests of the new invention in the near future. One or two well-known pilots who have tried the new propeller privately are satisfied that it fulfills all the claims the inventor puts forth.—Air Service News Letter.

Flame

By C. A. French[1]

Semi-Annual Meeting Paper *Illustrated with* Diagram

STATING that the knowledge now available does not permit an exact scientific definition of flame and giving the reasons, in this paper the author regards flames as gases rendered temporarily visible by reason of chemical action, discusses their physical rather than their chemical aspects and, unless otherwise indicated, refers to the flames of common gasoline and kerosene only.

To gain a reasonably clear understanding of the requirements and characteristics of the different kinds of flame, it is necessary to begin with a study of atoms and molecules. The author therefore discusses the present atomic theory, the shape of the atom and molecular structure, and follows this with a lengthy detailed description of the beginning of combustion.

The requirements and characteristics of the inoffensive variety of combustion are considered next and nine specific remedies are given for use in accomplishing the burning of heavy fuels with a blue flame in present engines. Oxidation and flame propagation are then discussed, the statement being made and amplified that it is likely that kerosene and gasoline can be more effectively burned by stratifying the mixture so that ignition occurs in a very rich portion which burns out into an excess of air, or a supporting atmosphere.

THE present state of our knowledge does not permit of an exact scientific definition of flame, for the reason that it may be the result of either electrical, thermal or chemical action, or, perhaps, a combination of two, or all of them. Flame does not necessarily indicate combustion. The flames in the Moore tube, the Geissler tube or the mercury vapor lamp, do not arise from combustion; neither can their glow be attributed largely to thermal action. Solar protuberances, according to the common view, are gases whose glow is of purely thermal origin, but colorless gases in a tube cannot be made to glow by thermal action alone.

Combustion, either slow or fast, is not always accompanied by flame. Burning hydrogen and oxygen, if both are pure and dustless, make no visible flame even in the darkest room according to the experiments of J. S. Stas. This is consistent with the fact that the line spectrum of hydrogen lies wholly within the ultra-violet. In the combustion of ethylene and chlorine the attendant radiation is below the pitch of visibility. In catalytic flameless combustion, which may begin with the hydrocarbon mixture and catalyst below zero fahr. and end 2000 to 3000 or more degrees above, there is no flame whatever, nor does the catalyst propagate flame even when surrounded by an excess of very rich combustible mixture. Surface combustion, which is entirely distinct from catalytic flameless combustion, may be regulated so as to show no flame, but that is on account of the very great luminosity of the white hot refractory surfaces back of the transparent blue flame. It will always cause a visible flame if an excess of mixture is supplied. The cause of transparent flames is doubtless largely electrical, while the cause of the opaque luminous red, yellow and white flames is probably almost entirely thermal.

A consideration of these facts will show the present impossibility of a strict definition. For the purpose of this paper, flames will be regarded as gases rendered temporarily visible by reason of chemical action; their physical rather than their chemical aspects will be discussed; and, unless otherwise indicated, it will be understood that only the flames of common gasoline and kerosene are referred to.

Many combustion phenomena can be explained only by the assumption that in normal blue flame the fuel burns from the molecule. In explosive combustion present-day gasoline and kerosene refuse to burn with an entirely blue flame under the conditions we use them. They burn with a very objectionable luminous sooty flame, which causes detonation and carbon deposits; while lighter fuels of the same general character burn in an inoffensive manner and give much higher thermal efficiencies. To gain a reasonably clear understanding of the requirements and characteristics of the different kinds of flames it is necessary to start with a study of atoms and molecules. Dr. Irving Langmuir says of atoms, "If a lump of ordinary matter the size of a baseball could be magnified to the size of the earth, the atoms in it then would have become about the size of baseballs." Atoms are believed to be composed of charges of positive and negative electricity. The positive electricity is concentrated into a very small particle called the nucleus, located at the center of the atom. The negative electricity exists in the form of electrons which arrange themselves in space around the nucleus. The electrons in different kinds of atoms are alike, but there are as many different kinds of nuclei as there are chemical elements. These differ from one another only in the amount of positive electricity they carry. For the simplest element, hydrogen, the nucleus has a unit positive-charge which is able to neutralize the charge of a single electron. Thus a hydrogen atom consists of the nucleus and a single electron. The next element, helium, has a nucleus with a double positive-charge, and the atom thus contains two electrons. Atoms of carbon have six and oxygen eight electrons. The electrons are not stationary but each revolves in its own orbit about a certain equilibrium position. It is thought that all atoms occupy about the same spaces.

The Shape of the Molecule

As atoms are thought to be spherical, it is possible that molecules usually are of the same compact symmetrical shape; at least their behavior in combustion is best explained by this assumption. If we take any number of ½-in. balls less than 13, and arrange them in a symmetrical spherical form, it will be seen that none is entirely covered and cut off from contact with the outside. By taking 13 balls it will be found that there is one ball in the center that is entirely surrounded. As we know that nature abhors a vacuum, we imagine that there is one atom in the exact center of any ordinary stable gaseous molecule. We find that by starting with one ball, or atom, in the center we can arrange 12 more

[1] Gas power engineering department, International Harvester Co., Chicago

around it so that all of the 12 will touch it. The arrangement will be symmetrical and the group will resemble a sphere. As there is no other equally symmetrical arrangement of spheres it is reasonable to assume that 13 atoms are the nucleus for any larger number. Hexadecane, $C_{16}H_{34}$, the largest molecule usually found in kerosene, has 50 atoms. Such a molecule would be likely to have 13 atoms inside and 37 on the outside. While 37 atoms would not quite symmetrically cover the 13 inside ones, if all of the atoms were rigid and unyielding, still there would perhaps be enough elasticity to the whole mass to allow the outside to be fairly symmetrical; there would therefore be three layers of atoms in such a molecule.

Molecules are thought to be vibrating and rather reacting on one another as they come near each other at rates depending upon their temperatures. In a mixture of combining proportions of air and fuel molecules the molecules of fuel, nitrogen and oxygen could bombard each other for days without starting oxidation, as it seems that some forms of chemical action between molecules are impossible. We know that two atoms, or one molecule, of hydrogen unite with one atom, or one-half molecule, of oxygen, and that one atom of carbon unites with first one atom of oxygen and the carbon monoxide formed by this union later unites with one more atom of oxygen. In other words a hydrogen molecule is satisfied with an oxygen atom, while a carbon atom requires an oxygen molecule but it can only use half of it at a time. It seems certain that the oxygen must be dissociated and ionized before combustion can begin. It is known that the radiation of a hydrogen flame is entirely in the ultra violet; that ultra violet rays dissociate and ionize oxygen; that oxygen ions spontaneously ignite many organic substances. Other means of producing oxygen ions will be discussed later, but as the blue flame of the electric spark we use for ignition is sufficient to ionize oxygen we are now ready to start the combustion of a 50-atom fuel molecule.

Beginning of Combustion

The electric spark ionizes enough oxygen to start the combustion of some one or more of the 37 atoms on the outside of the molecules. The ultra-violet rays from the burning of the first atoms ionize enough oxygen for the next few atoms but evidently not much more, for the blue flame never "runs away" or causes detonation as it would likely do if there were a large excess of ions. During the combustion of the outside layer of the molecule each atom is being bombarded by molecules of nitrogen and molecules and charged ions of oxygen. As the fuel atoms burn they send out new molecules of water and carbon dioxide, two first-class commercial fire-extinguishers, to replace the oxygen with which they united. If we imagine the atoms in the outside layer of the molecule to be about $C_{12}H_{25}$, there would be 24½ new molecules of carbon dioxide and water to replace the 18¼ molecules of oxygen used. The flame during the entire combustion of the outside layer of atoms is the perfectly unobjectionable transparent blue flame of almost entirely electrical properties with which every housewife is familiar from long use of it in the gas range or blue-flame oil-stove.

When this combustion started, assuming that there were no burned gases present from a previous explosion, each fuel molecule was surrounded with 93 N_2, and 24½ O_2, but when the 37 outside atoms have burned away we find 93 N_2, 12 CO_2, 12½ H_2O and only 6¼ O_2. It would be extremely difficult, if not impossible, to propagate a flame in a cold mixture of these proportions. A hydrocarbon flame cannot be propagated in an atmosphere containing less than 17 per cent of oxygen. With 117½ other molecules in the way, all of them the very best kind of fire-extinguisher, the 6¼ molecules of oxygen must have considerable time if they are to reach the remaining fuel atoms. In the meantime the 13 inside atoms have been subjected to the full flame temperature in the absence of air. If heated sufficiently in the absence of air all hydrocarbons will dissociate into hydrogen and lamp black. Probably some of the atoms immediately recombine into much smaller molecules; conditions at this time favor the formation of very small, highly endothermic hydrocarbons, such as acetylene, C_2H_2; but in any event there is much free hydrogen and free carbon.

Free carbon atoms tend to form aggregates of tangible size, far too large to burn quickly, among which the free nascent hydrogen burns heating them to incandescence. The flame now becomes first red, next yellow, then intensely luminous, opaque and radiant. The interstices between the solid carbon particles act as miniature refractory-lined reverberatory furnaces in which the free hydrogen is burned, thereby raising the temperature of the burning mass several hundred degrees. When the flame was in the stage of burning the outside layers or the blue stage only about 8 per cent of its energy was in the form of radiant heat; now more than 30 per cent of it is radiant.

When dissociation or cracking occurs at high temperature there is a large production of charged ions of probably all constituents of the mixture. A pressure wave, per se, probably could not be made to travel through molecular air in excess of the velocity of sound but charged ions undoubtedly greatly exceed that velocity. We will imagine that by this time one-quarter of the mixture is inflamed. The flame-front is still blue but the flame around the spark-plug, having been ignited first, has burned off the outside layers of the fuel molecules and has, by reason of the dissociation of the inside layers, arrived at the white-flame stage. Radiant heat with the velocity of light, and charged ions at something greater than the velocity of sound, are being sent out by the white-flame spot. The transparent blue-flame area between the flame-front and the white spot offers no resistance to the radiant heat and probably not very much resistance to the passage of the ions.

In air the vapor of hexadecane, $C_{16}H_{34}$, is very dense and opaque as the molecules are very large. Radiant heat is incapable of heating transparent vapors or gases, but it is absorbed in great quantities by a vapor as opaque as that of hexadecane. Heavy-hydrocarbon vapors when subjected to radiant heat of a moderate temperature will crack into smaller hydrocarbons when the cracking is done in the presence of enough air or neutral gas, but if subjected to radiant heat of a high temperature, if in the presence of air, they will ignite as they crack. Neither the radiant heat nor the charged ions can penetrate the dense cloud of vapor beyond the flame-front to a very great depth, but between them they instantly crack some of the molecules and ignite a very large quantity of highly compressed unburned mixture. This action causes a sudden severe increase in pressure, which, on a time and pressure diagram, shows a high peak occurring some little time after ignition.

This new flame very soon reaches the white-flame stage and causes perhaps another auto-ignition of a still more remote portion of the unburned mixture, causing a second pressure-peak. The more opaque fuel molecules would show a greater number of auto-ignitions or pressure

peaks than those of less opacity. It is easy to imagine that if a cylinder were large enough the pressures and temperatures would ultimately accelerate auto-ignition to a detonative rate of burning. Auto-ignition is often seen in forest and prairie fires where ignition occurs ahead of a flame-front when there is no possibility of sparks being carried to the area ignited. In experiments with burners auto-ignition is often seen when opaque vapor becomes ignited from a white flame some distance away with which the unignited vapor has no connection. There is little probability that a pressure wave causes auto-ignition as it would simultaneously ignite the whole body of unignited mixture, and we know that kerosene, for example, usually gives three pressure peaks, fuel oil five, etc., which seems consistent with the differences in the opacity of their vapors. There is no doubt that acetylene is occasionally formed and detonated. A glass window in the cylinder of a detonating engine on rare occasions shows a flash that is much more blinding; the noise is much louder than the ordinary detonation. Apparently this happens only with rich mixtures and an early spark.

It should not be imagined that the rate of oxidation increases after a dissociation, for such is far from being true. The rate of *inflammation* increases very considerably, but a careful study of the mixture proportions and ingredients after dissociation occurs will show that further oxidation, of the carbon at least, cannot be otherwise than a very slow process.

Before ignition there are 118 volumes of air, of which 80 per cent is inert nitrogen, with 1 volume of kerosene vapor. After the first 37 atoms of fuel are burned from each fuel molecule we have 1 fuel volume with 6¼ volumes of oxygen distributed through 117½ volumes of inert gas, hydrogen, carbon dioxide and water. We now have 1 fuel volume in 123¾ volumes of supporting atmosphere, but the fuel molecule is actually much smaller than the space it is vibrating in, and the supporting atmosphere is spread out to an enormous volume to include the vibrating space for its molecules. If we consider that the fuel vapor molecule is the ultimate mechanical division of the liquid fuel, then the actual volume of the molecule is proportioned to its weight. A 1-lb. molecule of kerosene requires about 338,000 cu. in. of air for complete combustion. After the combustion of the first layer of the 37 atoms of fuel, the atmosphere of the gases surrounding the remainder of the fuel molecule will occupy about 27,500 times the volume of the fuel, or a sphere of 30.2 times the diameter of the fuel molecule. The proportions are the same for a pound molecule, gram molecule or a single molecule.

Rich mixtures and unvaporized fuel greatly aggravate our combustion troubles. Inasmuch as it is positively known that hydrogen and carbon require definite quantities of oxygen for their combustion, it is not likely that we will ever be able to use rich mixtures, as we now use them, without undesirable complications. Unvaporized fuel has little opportunity to burn in a normal manner as by the time it is vaporized and ready to burn the oxygen supply is much depleted and the dilution with burned products makes it exceedingly difficult for the oxygen to reach it in time to oxidize any of it before dissociation occurs.

Inoffensive Combustion

Having studied a very inefficient type of combustion, we should now study the requirements and characteristics of the inoffensive variety. It should be understood that unless complete dissociation occurs immediately previous to ignition, any kind of a visible hydrocarbon flame cannot be propagated without an initial area, or period, of transparent blue flame, in which the air and fuel are in explosive proportions. Whether the fuel is burned in a supporting atmosphere, as a homogeneous explosive mixture, or even in a complete inversion of combustion, i. e., the burning of air in an atmosphere of fuel, makes not the least difference with the flame characteristics or color in the initial area or period. Entirely green, lavender, red, yellow or white flames cannot be propagated except as above stated, nor can they be maintained if too widely separated from transparent blue flame. If a yellow flame is examined through a yellow color-screen, it will be found to be permeated with a thin blue flame, and if a supporting atmosphere is available it will be seen that the yellow spot is entirely surrounded by blue flame. This is also true of spots of green, red and white when examined through the proper color-screens. In the oxidation of stable fuels spots of green, red, yellow or white indicate either a temporary or a permanent lack of oxygen, and the fuel atoms that actually cause spots of those colors are not at that instant burning. Hydrogen makes no visible flame; nor does carbon in burning to carbon monoxide; carbon monoxide usually burns with a transparent blue flame; therefore, a transparent blue flame is the only *visible* sign of oxidation. Spots of any other color indicate the cracking of the fuel into new smaller hydrocarbons and the large production of carbon monoxide, or the complete dissociation into free carbon and free hydrogen.

In the blue flame the reactions are simpler, more complete and the flame is more compact than any other. The molecules are in more rapid vibration and the oxidation is completed in much less time than when dissociation occurs. It has only about 8 per cent of its energy in the form of radiant heat, it is incapable of depositing soot, and its progress is not seriously affected by contact with cold surfaces. The only known requirements of blue flame are enough air and a fuel that will remain in the molecular state until fully oxidized. Nearly all liquid and gaseous hydrocarbons can be burned with an entirely blue flame, but, beginning with molecules of 12 atoms, more time for the burning must be given as the molecules become larger. Leaving out the ethers, the acetylenes and a few other hydrocarbons that are incapable of burning without more or less explosive dissociation, it can be said that any fuel molecule of 12 atoms or less will burn with an entirely blue flame under any pressure so long as there is no excess fuel.

There is, of course, what might be called a gradual decomposition of the fuel molecule even in a normal blue flame. Products of a limited oxidation of kerosene by catalytic flameless combustion are composed of a large number of alcohols, aldehydes, acids, and saturated and unsaturated hydrocarbons. In the green area of the Bunsen flame there is a very great amount of cracking into new molecules but so long as complete dissociation does not occur the flame does not become luminous. In the so-called wickless blue-flame kerosene-stoves small jets of air are burned in an atmosphere of kerosene vapor until the fuel molecules are cracked down so small that they will burn above the stove in a supporting atmosphere without luminous flame. It is apparently impossible to produce complete dissociation when enough air or neutral gas is present.

Fuels of the benzol series can seldom be made to burn explosively with a white flame unless a great excess of fuel and very high compressions are used. They can be caused to dissociate and make a cloud of black fluffy carbon, but as benzol series molecules are all small, they

do not dissociate until practically all of the oxygen is used; there being very little oxygen left after dissociation, the free hydrogen usually cannot burn enough to heat the carbon particles to incandescence. Used in stoichiometrical proportions such fuels probably cannot be made to detonate under any pressure. Fuels of the saturated series, when used in excess, have more tendency to become luminous; they are almost certain to have some large molecules as they are nearly always a mixture of a large number of different members of the series.

For every fuel molecule larger than 12 atoms there is a rate of oxidation that will cause it to dissociate, but for use in present explosive engines a molecule of 20 atoms or less would burn fast enough to be perfectly satisfactory, provided that there were no highly endothermic bonds in it. Its vapors would be so nearly diathermous that they could not be much affected by radiant heat. Fuels having the largest molecules have the most opaque vapors. The large molecules cannot burn rapidly without dissociation. The excess of ions from the dissociation and the radiant heat from the incandescent free carbon particles cause auto-ignition in unignited portions of the mixture. Therefore, to burn heavy fuels with a blue flame in present engines, one or all of the following remedies should be used:

(1) Thoroughly vaporize fuel
(2) Retard speed of oxidation
(3) Crack opaque vapors before ignition by use of radiant heat
(4) Raise compression and use reasonable excess of air
(5) Ionization previous to ignition
(6) Induce great turbulence
(7) Destroy reverberatory action of combustion-chamber walls
(8) Eliminate pockets in the combustion chamber
(9) Locate spark-plug in exact center of combustion-chamber

Oxidation and Flame Propagation

Oxidation can be retarded by careful cooling of the combustion-chamber, and by the use of plain diluents such as an excess of air or cool exhaust gas. The compression should be high, 125 lb. or more, to gain in thermal efficiency. The diluents can then be used with more effect and economy than when the dilution is secured by lowering the compression. It might be worth while to try a very small amount of chlorine as a diluent, as this substance is an ionizer and whenever a hydrogen atom is freed from a molecule, leaving the molecule in an unstable equilibrium, the chlorine would be likely to replace the hydrogen and preserve the molecular structure.

To best promote flame propagation the oxygen might be ionized by some of the catalytic processes. Great turbulence also accelerates inflammation and aids in keeping temperatures down by the scrubbing action of the burning gases upon the cold walls. To decrease the noise of detonation and to prevent extremes of temperature the combustion-chamber should be without pockets and very compact, *but without parallel surfaces*, so that neither heat nor sound can be concentrated by reverberatory action. The spark-plug should be located so as to give the flames the shortest possible travel.

It is likely that kerosene and gasoline can be more effectively burned by so stratifying the mixture that ignition occurs in a very rich portion which burns out into an excess of air, or a supporting atmosphere. If properly done detonation could not occur as the fuel would occupy but a small place in the combustion-chamber. Being a very rich mixture the rate of inflammation would be high. Complete dissociation would not be likely to occur and could not cause auto-ignition if it did, as there would be very little opaque vapor beyond the flame-front. A well vaporized very rich mixture burns first blue, then green, the green indicating a cracking into new smaller hydrocarbons. If enough air is available immediately after the cracking the green flame becomes blue again and is in no way objectionable except that it is about 50 per cent more radiant than the blue flame. With this method the air is not throttled; the fuel only is governed. An engine using this method of combustion would have steam-engine characteristics in a reasonable degree, without sacrificing economy, which is much more than can be said for present engines.

THE DISCUSSION

O. B. Zimmerman:—To my mind, Mr. French's paper is one of the most constructive that has been presented to the Society. It is hardly to be expected that in this first approach to a subject on which the state of our understanding is still very vague, or at least on which the data concerning the phenomena are not well dispersed, the data will be correct according to the understanding of certain individual technologists, but we must admit that this paper does open up a vast and necessary field for study and research along chemical and physical lines. Until we can form correctly a clear understanding of the structure and characteristics of the medium we are dealing with, we shall not arrive at the best results. Should a doctor have a case of smallpox that he treats as measles, he might arrive at a cure but still not do it in the best way. As engineers, altogether too many of us are endeavoring to solve the problems of the internal-combustion engine in a purely mechanical way, without due consideration of the physical and chemical requirements of the medium with which we are dealing.

Credit must be given to Mr. French for the deductions he has given us from a careful review of the subject. The paper is particularly illuminating in enabling us to visualize the probability of the method of flame propagation, the peculiar mixing of burnable and burned gases during this phenomenon, the probable effect of the shape of the container, the dispersion of heat and pressures and, finally, the combined effects of these mixed activities on efficiency. Another feature that it emphasizes is the undoubted probability that if the refineries will devote more attention to an endeavor to produce liquid fuels with regard to the real requirements of an engine, such as a fuel of a simple series of molecular structures rather than those having a wide range of complex structures as we often have today, both fuel producers and consumers will be benefited. That such a simple structure is possible in a thoroughly commercial way is being demonstrated today in a going refinery. The results show that the structure of the molecules as arranged in a paraffin series is not necessarily the best one for the economical operation of the internal-combustion engine. It is possible commercially to rearrange this structure by chemical means, thus making a more efficient fuel than we have now. If we are then really to develop the internal-combustion engine into its most economical and practical form, we must delve into the science of the unknown, as Mr. French has done.

Prof. Robert E. Wilson:—I wish to thank Mr. French for stimulating thought on the subject of just how flame is propagated. I, for one, am planning to make some experiments soon which should tend to verify or refute his conclusions. I believe Mr. French will admit that his theory of flame propagation is but an hypothesis unsup-

ported as yet by sufficient experimental data to warrant our acceptance of it without further question. Furthermore, a number of statements are made in Mr. French's paper which appear to demand correction.

Atoms and molecules are real things; they exist. The mere fact that we cannot see them is no reason for not taking all the evidence obtainable from a variety of sources and making the best possible working drawing of their structure. To do without definite pictures of atoms and molecules is just as much of a handicap for the chemist as it would be for an automotive engineer to try to construct an engine on the basis of a hazy idea instead of accurate drawings. Unfortunately, the working drawings of atoms and molecules that Mr. French has presented do not fit in with certain of the known facts with regard to their behavior. For instance, the statement "it is thought that all atoms occupy about the same spaces" is not reasonable from what we know of the constitution of matter. When the number of separate electrons in the atoms varies from 1 in the case of hydrogen up to 92 in the case of uranium, it seems impossible that the volume could be the same. As a matter of fact, on the basis of practically undisputed measurements and calculations it is known that there is a variation of *at least* fivefold between the volume of the smallest and the largest atom.

Proceeding from the atom to the group of atoms, or molecule, which is the characteristic unit of all our chemical compounds, Mr. French postulates a type of molecule that is merely a group of spheres of uniform size tied together very much like a bunch of grapes, the spheres all being bound close together in concentric layers. Now we do know definitely, for reasons that Dr. Langmuir of the General Electric Co. has explained very clearly, that these molecules are not arranged in any such casual grouping, but that each atom is tied to one or more others in a certain definite fashion. Also, we know whether the resulting structure is a straight chain, a branched chain, or a ring with or without branches. Unfortunately, Dr. Langmuir has not as yet gone into the structure of very many organic compounds, but, simply by applying his theory to organic compounds, E. C. Crocker of the research laboratory of applied chemistry at the Massachusetts Institute of Technology has found it possible to work out very definite structural formulas. The upper portion of Fig. 1, for example, represents a molecule of normal hexane, one of the low-boiling constituents of gasoline, except that on paper the cubes representing the carbon atoms can be pictured best as squares. These cubes should not be conceived of as solid material, but as models the corners of which indicate the positions of the electrons in space. In the figure the corners of the squares therefore correspond to *pairs* of electrons, in two planes, one above the other, that are held in common between two atoms.

We can say, then, for purposes of visualizing the stresses involved, that in a molecule of normal hexane we have six carbon atoms attached end to end, making a straight chain characteristic of the paraffin hydrocarbons. The hydrogen atoms are much smaller and are attached to the free corners. Now we definitely know that this chain is not normally bent or tied in a knot, although it is not a rigid body. If anything hits such a molecule, it will bend like a piece of spring steel. These hydrogen atoms, having light, positive charges, tend to repel one another and it takes a great amount of force to bring them together. Such a structure is obviously far different from the disordered mass of tightly packed spheres postulated by Mr. French.

Probably Mr. Crocker's most important contribution is in his representation of the structure of benzol. It also has six carbon atoms joined together, but in this case they are in the form of a ring, which can best be represented on paper as at the bottom of Fig. 1. Here each corner of each triangle represents a pair of electrons held in common between two atoms and the dots represent small electrons vibrating in the plane of the ring.

I wish to thank Mr. French for suggesting an explanation of our getting a luminous flame when we have a long molecule. He says that we burn off the outside carbon and hydrogen atoms and that this heats up the inside ones. That is not true, because they are not packed together in the way which he postulates. If, however, we take a straight chain, such as that pictured in Fig. 1, the hydrogen atoms are on the outside where they can combine with the oxygen, and they are obviously the first thing that burns. Now we have much evidence that oxygen cannot force itself in between the carbon atoms in such a chain. The carbon atoms must therefore burn only on the free end. Obviously, if we have a long chain, we burn off the hydrogen atoms instantly, and then we start to burn the chain of carbon atoms from each end. If this chain is long enough, it is likely to combine before it is completely burned with other similar carbon chains that have been stripped of their hydrogen, thus forming tiny solid particles of carbon made luminous by the heat of the combustion. This gives us a very definite picture of why a long chain behaves so differently from a short chain. There is, however, no sharp change as postulated by Mr. French when the number of atoms exceeds 13, the number which would be in his inner layer or nucleus of spheres.

The statement in Mr. French's paper that "one atom of carbon unites with first one atom of oxygen and the carbon monoxide formed by this union later unites with one more atom of oxygen" is also contradicted by the best evidence available. The Bureau of Mines has definitely shown that under ordinary conditions of combustion one atom of carbon combines directly with one molecule of oxygen containing two atoms. Then when the carbon dioxide goes on up through the hot fuel-bed, another atom of carbon is likely to grab one of the oxygen atoms from carbon dioxide, forming two atoms of carbon monoxide. Reasoning on the above basis, Mr. French has suggested that if combustion is to take place, it is first necessary to divide the oxygen into atoms. This conclusion is certainly rendered less secure by the evidence that carbon does combine directly with a full molecule of oxygen according to the best evidence available.

The statement is made that "a hydrocarbon flame cannot be propagated in an atmosphere containing less than 17 per cent of oxygen." That depends on the temperature and pressure to a very considerable extent, but even at an ordinary temperature acetylene will explode without any difficulty in a mixture containing much less than 17 per cent of oxygen; in fact, I have exploded mixtures containing as low as 6 per cent of oxygen.

F. C. MOCK:—Will Professor Wilson please continue his explanation as to what happens to the chain molecule during cracking, as well as at the initiation of spontaneous combustion, if such a thing occurs? In the latter case, for instance, whether the carbon burns off the end of the molecule or the molecule breaks in the middle.

PROFESSOR WILSON:—I should have said that while oxygen cannot pry itself in between the carbon atoms in that chain, it is nevertheless possible that a long chain that is, of course, in constant violent motion will break

at high temperatures; then it is free to oxidize at several points. So, the cracking that we get, or the breaking down into smaller units, would tend to make a less luminous flame.

As to what happens in spontaneous combustion, it is simply a question of reaching the ignition temperature, which can be accomplished in a variety of ways. There is no difference between spontaneous combustion and any other kind of combustion. A temperature is simply reached where the compound is oxidizing rapidly enough to propagate a flame.

MR. MOCK:—It seems that the larger the molecule the more nearly the temperature of spontaneous combustion approaches that for cracking. Is it not highly probable that the two kinds of action will occur almost at once during what we call detonation? I mean that when a temperature is reached in the cylinder where one would occur, the other also would occur.

PROFESSOR WILSON:—I am not familiar with the precise facts, but it is certain that the ignition temperature of many of the products of cracking is considerably lower than that of the original large hydrocarbon molecule. It is therefore entirely reasonable to expect that on heating certain large molecules with air, cracking would begin before combustion, and that the very active smaller molecules thus produced would almost at once start to propagate a flame.

CHAIRMAN THOMAS MIDGLEY, JR:—There is a general relationship between auto-ignition and cracking temperatures but there are exceptions to it which prove that they cannot be exactly the same things.

Since reading Mr. French's paper we have experimented with the effect of chlorine upon the knock and find that chlorine is a very bad knock-inducing material, which is quite contrary to the prediction made by Mr. French.

C. A. FRENCH:—My statement was not intended to imply that atoms are compact. The modern conception of the atom is that there is a positively charged nucleus surrounded by one or more negatively charged electrons. The electrons are at comparatively immense distances from the nucleus. This distance is probably fixed by their charges. As the nucleus has a unit charge for each electron, there is no good reason for believing that these charges are not all equal and that, regardless of the size of the atom, the electrons will always keep about the same distances from the nucleus, especially as there is more than ample room for them to do so, and as the repelling action of their negative charges would keep them from colliding. This would make all atoms occupy about equal spaces. I can imagine a hotel having 100 rooms, all of the same size, but each inhabited by a person of a different size from any of the others. Thus the 6-lb. baby or the 600-lb. giant would each have space enough in which to move about freely, but each would live in, occupy or inhabit equal spaces without actually filling the space he used.

Just what a molecule looks like no one knows, and perhaps no one will ever know. Many eminent physicists, chemists and scientists are accustomed to think of molecules as being spherical in shape. In the absence of any proof to the contrary we are entitled to assume that they are spherical if this explains best why a large molecule must burn slowly if it is to escape dissociation. Without denying that the atoms in a molecule are tied together in very definite chain formation, as Professor Wilson states, it would still be easy to bunch almost any kind of a long chain into a sphere, and almost any link might be left on the outside. This seems more consistent with the tendency of matter to assume a compact shape. Carbon,

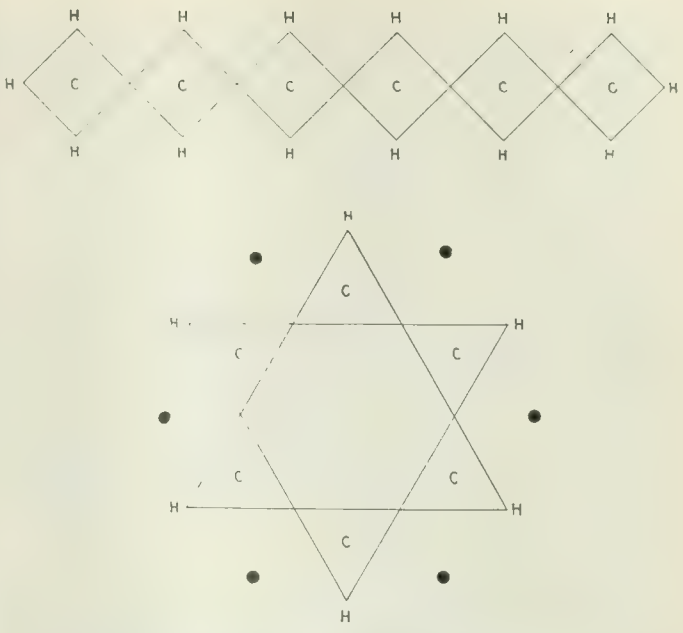


FIG. 1—THE CHAIN STRUCTURE OF A MOLECULE OF NORMAL HEXANE IS SHOWN IN THE UPPER PORTION AND UNDERNEATH THE RING STRUCTURE OF A BENZOL MOLECULE

when freed from the molecule, forms spherical aggregates that can be seen with the naked eye. Happily the extended chain conception of the molecular structure serves about equally well in proving that a certain amount of time is required to burn a large molecule without dissociation, which is the point that I particularly want to emphasize. For some reason oxygen cannot get to all of the atoms of the molecule *in time* to save them from dissociation if oxidation is too rapid. If we assume that the molecule exists as an extended chain the combustion would likely begin at each end and as it progresses toward the middle the dilution of the oxygen with water, carbon monoxide and carbon dioxide becomes greater, so that a certain amount of time must be allowed for the oxygen to reach the remaining fuel atoms. If the dissociation is extensive enough it produces auto-ignition in the unburned mixture ahead of the flame front. The new flame soon reaches the stage of dissociation and produces another auto-ignition. If a cylinder were large enough and long enough the velocity of propagation would finally reach a rate that would be limited only by the time necessary for the radiant heat and the charged ions to propagate flame, a rate certainly far in excess of the velocity of sound. Mallard, Le Chatlier and others are in fair agreement that the velocity of detonation in a long closed tube is 3500 to 3700 meters per sec. (11,482.92 to 12,139.08 ft. per sec.).

Experiments with gas turbines with the gas at very high temperatures and pressures have never shown that the gas cannot be made to move through a nozzle faster than the velocity of sound in the same mediums at the same temperature and pressure. Apparently, no nozzle velocities remotely approaching 3500 meters per sec. (11,482.92 ft. per sec.) have been reported. The Midgley indicator-cards show one detonation peak for Pennsylvania gasoline, three for kerosene and five for fuel oil burned in the same engine, thus showing one, three and five auto-ignitions. A pressure wave could produce but one peak in any fuel, and it could not travel 3500 meters per sec. (11,482.92 ft. per sec.). As we cannot make molecular air move faster than sound, it is certain that detonation is not directly due to pressure.

Whether carbon burns directly to carbon dioxide is a debatable question. I would like to believe that it does in the normal blue flame, but there is much evidence against this. Linseed oil annually causes hundreds, if not thousands, of fire losses from spontaneous combustion. In drying, which is really oxidizing, it gives off carbon monoxide and, in splitting the oxygen molecule to form the monoxide, liberates a charged oxygen ion which sometimes causes spontaneous combustion. Other hydrocarbons in the process of slow oxidation are prone to ignite spontaneously under circumstances that preclude the possibility of their ordinary ignition temperatures having been reached. Investigation seems to show that oxygen ions are invariably produced as a first step. If oxygen ions were produced as a first step, certainly carbon monoxide and water would be the next things to look for. Knox Harding of Chicago told me that he prepared 100 different combinations and that within three months 48 of them ignited. All of those in which the production of oxygen ions was arranged for ignited; none that were not so arranged ignited.

My statement that no kind of a hydrocarbon flame could be produced in an atmosphere containing less than 17 per cent of oxygen should have been qualified to the effect that a hydrocarbon flame can be produced only when there is a large number of ions following a dissociation or considerable decomposition in which there is really less of oxidation than decomposition. Even under such circumstances it would be impossible to propagate a flame with most fuels without a catalyzer or a very hot refractory surface. However, in any discussion of flames and possible mixture proportions it should always be understood that acetylene, ether and catalytic flameless combustion are excepted. Berthelot and Vielle found that liquified acetylene under 150-lb. pressure would explode with a brilliant flame, producing a pressure of over 5000 atmospheres without any air or any other supporter of combustion, but this was explosive dissociation without oxidation. It is different to burn acetylene explosively without much more explosive dissociation than oxidation.

Ether is a C_2H_5 radicle on each side of an O. Its vapor-tension boiling point and some other things are more characteristic of one of the radicles than of the molecule, showing that there is such a lack of cooperation between the radicles that we should expect it to have unusual properties. A very rich mixture of ether vapor and air, forced by 10-lb. or more pressure through an expanding nozzle into an exhausted tube 4 to 8 ft. long, dissociates and ignites at extremely low temperatures. Mixtures much too rich to ignite under ordinary circumstances are easily ignited by this method. Catalytic flameless combustion can be maintained with mixtures as rich as 2 to 1 by weight, but there is a very great amount of cracking and little oxidation.

I regret that the discussion has not brought out more ideas on the type of flame that should be used; for very definite reasons some types are preferable to others. We should decide upon the type and then learn how to produce it. Reports of investigations of combustion in closed cylinders usually fail to mention flame colors and characteristics, without which the reports are of doubtful value.

THE AUTOMOBILE INDUSTRY

SINCE the beginning of the automobile industry in America, 25 years ago, the number of cars manufactured up to the beginning of 1921 has been about 11,775,000, of which more than 700,000 have been exported. About 9,000,000 are in use, and 2,000,000 have been worn out, destroyed or abandoned.

The average term of service based upon the most authoritative statistics available has been about six seasons.

By the end of 1920 there was one car in use for each 12 people in the population.

The theoretical number of possible purchasers of motor vehicles seems to be limited to about 20,000,000. This is about the number of white, native-born men above the age of 21. It is also about the number of white American families. It is also about the number of persons earning money whose occupations are such as to make it appear possible that they might become motor-car owners.

At the end of 1920 there were about 42 cars in use for each 100 native white men of voting age. The number varied in different parts of the country from about 22 cars per 100 men in the East South Central States to 60 cars per 100 men in the Pacific States.

It seems impossible to compute any saturation point for the industry because the number of cars demanded will apparently depend for many years to come on the general prosperity of the country.

It appears certain that for some years to come new users of automobiles will largely be people of limited means who will purchase inexpensive cars.

Since 1916 the increases in the annual output of automobiles have largely been accounted for by the expanding output of Ford cars and of other relatively inexpensive makes.

Up to the present time the replacement market has never exceeded 500,000 cars in a year, but there is every prospect that it will shortly amount to at least 1,500,000 cars per year.

Present productive capacity of the automobile industry is more than 1,000,000 cars per year greater than would be required to maintain the existing use of machines in a constant status.

Unless exports of cars increase enormously it appears that the present productive capacity of the industry would be sufficient nearly to double the number of cars in use within the next few years. It appears extremely doubtful if foreign or domestic markets can be sufficiently expanded to take care of this capacity, and if they could it seems probable that some motive power other than gasoline would have to be developed to propel the cars.

It seems probable that extensive price adjustments will be made in the next few years, as the industry, with its great capacity, competes for purchasers among people and countries whose buying power has recently been sharply curtailed.—Leonard P. Ayres, Vice-President, the Cleveland Trust Co.

The Metallurgist and the Tractor

By C. S. Moody[1]

Minneapolis Section Paper

THE author considers first the materials available for construction, in connection with the S. A. E. standard specifications, and presents a comparison of the different metals with comments thereon. In regard to metallurgical problems the designer's first task is to determine what the various stresses in the parts are and their magnitude; hence, a true appreciation of the terms "shock" and "fatigue" is necessary; a somewhat lengthy explanation of their meaning is given.

The construction features of the different parts of the tractor are treated in general, no attempt being made to cover details; comments are presented on front axles, wheels, bearings, cylinders, valves, valve-seats, transmissions and gears. Heat-treating is then considered in some detail, three specific reasons for annealing before machining being given and five which are governing factors in regard to heat treatment in general.

I WILL not attempt a paper that is an original thesis but instead present bits of information gathered from time to time. This information is offered more with the idea of starting an argument than of imparting details and all thoughts herein set forth are expressed from the viewpoint of the tractor builder.

Materials

The standard specifications issued by the Society of Automotive Engineers suffice as a beginning for this address and we can use them as a foundation on which to build the remainder. A brief synopsis of our present knowledge put into a slightly different form may not be amiss. I refer to a paper[2] by Ira T. Hook of the General Motors Corporation entitled Factors Limiting the Use of Materials. Imagine a prismatic bar supported vertically at one end and extended to such a depth that its height or weight is sufficient to cause fracture. Then the length in feet equals the tensile strength divided by 12 times the weight per cubic inch. Table 1 gives us a fair idea of what we are working with.

TABLE 1—COMPARISON OF DIFFERENT METALS

	Length in tension, ft.	Length in compression, ft.
Cast Iron	6,400	32,000
Common Steel	15,000	30,000
High-Grade Alloy Steel	59,000	88,000
Hard-Drawn Copper	13,100	18,400
Duralumin	28,000	40,000

The proper uses of the various steels is a large study in itself. The tractor industry as a whole views steel as steel and alloy steel as alloy steel, no more and no less. The point I make is that alloy steels have characteristics which make them applicable to certain kinds of work. For example, we use S.A.E. No. 2330 nickel steel for shafts and parts which undergo deflection from the stresses applied, but we want high-carbon steel helped out with chromium on wearing surfaces. So much for the necessity of intelligent specifications. I assume that all are familiar with the S.A.E. standard steels; there are, however, one or two cases in tractor work where we must go outside of them as for example manganese steel castings.

Cast steel in the heat-treated condition has proved very successful for tractor parts, principally gear blanks, crawler treads, steering-arms and front axles. The common objections to cast steel are blowholes and shrinkage. They are foundry problems and excessive unsoundness should not be tolerated in vital tractor parts. For example, we use a 90-lb. heat-treated tractor gear that is heavily stressed. Thousands of these gears have been received and in the case of the company that supplied 90 per cent of them there have been no rejections and not over 10 had perceptible shrinkage or blowholes. This was purely a matter of foundry practice, which has been worked out satisfactorily to all concerned.

At present a number of firms are selling cast alloy steel that shows physical properties far above those of mild rolled or forged steel. After heat-treatment one well-known brand, composed of 0.40 per cent carbon, 0.35 to 0.45 per cent chromium and 1.25 per cent manganese, shows a 90,000-lb. tensile strength and will bend double. Another 0.30 per cent carbon, low chrome-nickel alloy will show 65,000 to 75,000-lb. yield point, 95,000-lb. tensile strength, an elongation of 16 to 19 per cent and a reduction of 25 per cent or over after heat-treatment. Other alloys with 2 to 3 per cent of nickel and 0.30 per cent carbon show about the same tensile properties.

With these physical values, together with the accompanying hardness, large slow-speed gears impossible to forge give fine service. The necessity for extreme hardness does not seem to be manifest with cut gears and enclosed lubrication in our newer tractor jobs. I will not discuss gearing more than to say that based upon our experience we have in the order of increasing wear cast iron, cast steel and manganese steel.

In large reduction gears we find that cast steel used in the carburized condition has proved very successful because, with intelligent handling and the generous sizes necessary for surface wear, we can do practically all that it is possible to do with forged steel, in spite of the larger grain-sizes generally prevailing in cast steel. In my personal experience I cannot recall one breakage in heat-treated cast-steel gears that is attributable to large grain-size as such. The shock properties of cast steel cannot equal those of forged steel but, when good judgment is used, this does not appear to be a hindrance until we get into the intensive type of tractor design.

Manganese steel is not used by the automobile engineer but is commonly met with in tractor design. It is used mostly in treads for crawlers and in drive pinions. It will show about a 56,000-lb. elastic limit with 105,000 lb. as a maximum, a 34-per cent elongation and a 35-per cent reduction of area. This steel, while ductile, resists abrasion to a marked degree. It cannot be machined, but must be ground, and is admirably suited for use for external or unprotected gearing; it runs well without lubrication in sandy or dry soil.

Malleable-iron castings, when carefully made and inspected, perform creditably in the place of untreated drop-forgings but, when put through many foundries on

[1] M.S.A.E.—Metallurgical engineer, Minneapolis Steel & Machinery Co., Minneapolis.

[2] See Transactions of *American Society for Steel Treating*, November, 1920, p. 140.

a production basis, the individual care seems lacking and breakages occur which do not manifest themselves in forgings. I have in mind shifter levers and front axles. Where the machining to be performed coincides with the sections most likely to show shrinkages and defects, malleable iron works very well, as in this way a real 100 per cent inspection is obtained.

Metallurgical Problems

The designer's first metallurgical problem is to determine what the various stresses in the parts are and what their magnitude is. This leads us into a true appreciation of the terms "shock" and "fatigue," which are ever-present in automotive design. Let us first look at the fracture of a failed part and see how it occurs. We have what is known as the elastic limit. The definitions for "elastic limit" or "working elastic limit" are numerous, but the failure is initiated when the first crystal in some isolated portion of the piece will no longer return to its original position after being stressed. The common method of determining the "true" elastic limit or yield-point is to stress the piece in tension and in compression. The highest stress that can be applied and still permit the piece to return to its original length is taken as the elastic limit. This is not the same point when either tension or compression is applied alone. Undoubtedly, the first slippage of the crystals occurs before the elastic limit is apparent as measured in usual tests.[a] We know that materials do break or fracture when repeatedly stressed below their elastic limit, as ordinarily termed, and we know, further, that the more closely their reversals in stress approach the common elastic limit in magnitude, the fewer are the number of reversals required to produce fracture. So, we see that the true elastic limit varies with the number of 100,000 times the reversal of stress is made.

When we have a service fracture that shows a series of rings arranged concentrically about a point, we call it a progressive or "fatigue" fracture because it extended over a relatively long period of time and resulted from repeated applications of stress within the apparent elastic limit; no one of the loads applied to the piece *by itself* could have produced failure. Consequently, for this repeated or repeated-and-reversed stress we desire a metal with high elastic limit. Because we get a high elastic limit, we usually get low ductility, that property which allows the metal to deform under load. We know that such a type of steel will not withstand sudden shocks. These shocks resolve the steel into one that will absorb work. From the simple laws of mechanics we know that, excluding the heat generated, work is the sustained exertion of pressure through space and is equal to the force multiplied by the distance traveled. If this is the case, sudden isolated loads do not of necessity need a high elastic limit, because we want the metal to deform and absorb these isolated shocks, and still retain the piece. With this understanding, we must weigh our problems and balance the shock properties against the fatigue properties of metals. The essential problem is, then, what are the real operating stresses? In this connection the fracture of broken parts often leads us to the proper solution of future problems. If one is particularly observant, this may save the firm many dollars; for example, in making unnecessary the replacement of a broken crankshaft for a 7¼ x 9-in. engine that has been improperly rebabbitted in the field, thus causing a deflection to recur repeatedly that results ultimately in a progressive or "fatigue" failure.

There is another feature that is too often overlooked in the tractor field, due to the fact that small production and local sales do not make the trouble evident in its proper magnitude, or as quickly as when the machine is operated under adverse conditions. Neglecting the notch effect is the engineer's greatest failing. The designer will literally spend days on a design and then leave a notch in a vital section of the finished work that will wreck his whole machine. One glaring example of the stresses that may be so produced is given in Handbuch der Materialienkunde für den Machinenbau, by Martens and Heyn, Vol. 2A, page 364. The investigator took a solid square bar of lead, notched it and broke it by impact from the solid side. He did this also with another unnotched bar. The volumes of the strained parts were as 1 to 3.76. The elongation was measured by 5-mm. (0.197-in.) squares made before fracture; they showed 120 and 70 per cent respectively for the notched and unnotched bars. But the real value of the localized stresses caused can be shown by the line at the bottom of the notch which, originally about 0.25 mm. (0.00984 in.) wide, was increased to 4.25 mm. (0.2382 in.) in width or 1700 per cent. The engineer should beware of notches.

The coefficient of expansion of different metals is too often neglected; the values of this coefficient at high temperatures are all too meager in our handbooks. As tractor engineers using kerosene-burning engines, we should look at the sections of cylinder-heads and see how the expansion can take place. Likewise, let us look at the sections of heat-treated gears and be sure that they can be heat-treated successfully on a production basis. We can generally accomplish almost anything in the tool-room at least once. In this connection, let us not depend on laboratory tests for strength and hardness when we work with 2-in. sections and test on a 1 or a ½-in. section. Nor should we depend wholly on the S.A.E. standard curves. I did this and had the painful experience of having "tonnage" steel bought for me which met all of the chemical specifications but failed to have the desired physical properties, as a number of expert steel servicemen can testify. I allowed for the size, which was 3½ in. to be exact, but did not allow for the quality or rather the lack of it, as the instructions in the S.A.E. Handbook state that the values given should be obtained without difficulty or that they are average values. The thought that I received from reading the instructions was that with average practice the results mentioned should be duplicated. We used the best practice, including preliminary heat-treatments, without any effect.

In our heat-treating we find further that the critical ranges of the various alloys have a marked effect on warpage and distortion. It can be said in a general way that the higher the alloy is, the less the warpage is and the less is the care that must be used in heat-treating. We find that in tractor sections that we have to use water for quenching, whereas the same steel for automobile sections can be quenched in oil.

Construction

In taking up the different parts of the tractor for individual examples, I do not aim to cover any details. We find frames made of cast iron and cast steel, as well as of rolled-steel sections. The use of pressed-steel frames is limited, pressed-steel parts being generally confined to hand-hole covers, valve-covers and base-pans.

The front axles are mostly drop-forgings, there being

[a] See Introduction to the Study of Physical Metallurgy by Walter Rosenhain, pp. 254-255; also an article by the same author entitled Engineering Relations of Shock and Fatigue, published in *Automotive Industries*, June 10, 1920, p. 1293.

a few built-up types. There have been some short-lived examples of cast-iron and malleable-iron axles. Cast-steel axles are being discarded because of blowholes that cause fractures. Few of these types have been heat-treated. For small production, cast steel produced by a first-class firm and heat-treated should be given first place, with the drop-forged untreated front axle for high production. I say untreated because I favor the larger section modulus in a tractor running-gear. The latter applies also to drag-links and steering-arms, which nevertheless should be heat-treated and designed for shock properties. In steering-knuckles we find a fairly general tendency toward anti-friction bearings, with little foundation for it other than automobile practice. We have produced our small tractor successfully without them, after eliminating some slight difficulties. Where we originally took care of wear by carburizing, we had fractures showing both fatigue and shock as having been the cause. Later we carburized the wheel bearing only and eliminated the trouble to some extent. Now we are using S.A.E. No. 3140 steel, which we feel gives an even better job on account of production as well as service.

I feel that the design of tractor wheels opens the largest field for the consideration of better materials. No one has to our knowledge given the wheel the scientific study it deserves. As I have heard it expressed, "Any fool can design a wheel"; many of them have done so but, if the history of the tractor industry were written, more failures would be found in the wheels of so-called successful tractors than in any other part. Tractor wheels support, first of all; they must do that, but how many operators consider the stresses they put on front wheels in cramped positions, as they apply full power in turning in a soft field? Yet the user in many cases expects a gratis replacement if failure occurs.

Wheels that will stand up can be built with less weight. Then, too, spokes break from fatigue. Let us have light wheels of good material amply fastened and supporting the rim. The same result can be accomplished by using a heavy rim; I venture the opinion that 75 per cent of wheel troubles can be eliminated by stiffening the rim.

In tractor engines there are one or two parts that come in for a great deal of trouble not encountered in automobile engines. Lubrication defects and crankcase oil dilution with kerosene play havoc with bearings. This was particularly true in the case of the older heavy-type machines, with which the operator who could get through the week without overhauling the bearings was a wonder. This we successfully combated with proper carburetion, hard babbitt (S.A.E. No. 24) and hardened crankshafts. By applying what we learned on the big machines, the small ones became easy. We find a serious condition with the valves in kerosene engines. Cylinder design and the manner of supporting the valve probably cause the majority of our troubles. Valve-seats are not produced with the precision they rightfully deserve; witness valve-seats after they have been given the so-called "perfect seat." Wipe one absolutely clean, burnish it in and note the result. This is not a plea for better valve-seats unless we want to use cheaper valves. An imperfect valve-seat allows hot gases to bring the valve up to oxidizing temperature, and then we have valve trouble. The oxidizing temperature of the valve material is the key to the problem. Let your valve heat above this temperature, even with a perfect seat, and you are lost.

Cast iron would be the prize performer here if we could only fasten it to an alloy stem satisfactorily. Our firm has put out hundreds of large slow-speed jobs with cast iron valve-heads and mild-steel stems and has not known valve trouble, but the small higher speed engine, with high-temperature exhaust coming at such frequent intervals, does not allow the stem to keep the valve cool enough to prevent oxidizing. We are offered a multitude of valve materials that were used in "Oxyrolls" or some other airplane engine and sound attractive to the manufacturer having valve trouble, whereas all that is necessary is to put a thermocouple in the hottest exhaust passage, get the working temperature and then pick the valve material that has the lowest price with the oxidizing temperature above that in the manifold. I do not mean that we should have poor workmanship in a valve-seat or elsewhere. Other items in our engine are practically the same in respect to materials as in the case of good automobile practice.

In transmission construction, let us dispose of the open geared type by saying that if the designer does not care more for his work than to leave it exposed, no thought should be given to his material; it will wear out anyway unless he will buy manganese steel. Where the bearings are not operated on the shaft, I believe that transmission shafts should be constructed of nickel steel, giving the best shock properties possible. This applies to the smaller uptodate tractors now on the market. Where the bearings operate on the shaft, we must necessarily carry the hardness higher than otherwise, and a little chromium in the shafting steel does wonders. But let me warn you to keep the elastic limit high under these bearings or look for trouble. We will have to condemn the bearing manufacturers here, as apparently they cannot give any reliable data; you must work out your own solution. It is better to put a race under the bearing and do it right. It may save you gray hairs and cold dollars.

On enclosed gears, we can follow automobile practice very profitably on the smaller sizes, with their consequent higher speeds. In the larger-size and slower-moving gears, our firm's experience can be recited. Our large reduction-gears, which are about 22 in. in diameter and have a 1½-in. face, were originally designed for 0.35 to 0.45 per cent carbon steel heat-treated but, owing to the thin section and danger of warping, they were not heat-treated in our experimental machines. They showed excessive wear even when operating in an oil-bath. This test also seemed to indicate that we could not depend on the cast steel we could then procure; so, when a rolled-steel gear-blank salesman came along, we welcomed him with open arms. On the arrival of these blanks we found we could heat-treat them without excessive warping; that is, for a 100-r.p.m. gear. This then was our program, but the steel did not seem to harden uniformly, so we found a drop-forger who thought he could produce these blanks in competition with the rolled-steel maker. But the number of our culls which would not harden properly kept mounting higher. We could very seldom quench these gear blanks twice without excessive distortion. About this time we felt we were on the wrong track and set about producing a perfect gear. This we believe we have done with no additional expense in two cases and for less cost in a third. The gears now are in production on our 20-35 tractor. We started with the idea of using a ring-gear shrunk on a spider, which we learned was giving some companies trouble in a certain measure by the rings splitting off the spider at a point corresponding to the unopened end of the split bar from which it was forged. Metallurgically this method is fundamentally wrong for a heat-treated forging, because strains were left in the ring. They were using about a 0.40 per cent carbon steel shrunk on in water, I believe. Our method is to cut

our gear teeth in a very thin ring, of S.A.E. No. 3140 steel which has been given a heat-treatment prior to machining. This ring is machined about 0.016 in. small on the inside, and on the outside of the cast-iron spider we cut teeth or splines about 3/64 in. deep and of about ¾ in. circular pitch. This is done on a Fellows gear-shaping machine with the cutter ground back to the pitch line, only one cut being necessary. The gear is then quenched in oil from the proper temperature, no attempt being made to hold it accurately to shape. The drawing operation calls for a high draw to get a No. 475 Brinell hardness. When at the drawing temperature used, the gear opens up so that it will easily slip over the spider where, on cooling, it shrinks in place. The satisfactory part of this operation is that no excessive strains in relation to the elastic limit are left in the gear, and yet a very good press-fit has been secured.

As a test for strain, we cut one of the gears through with a rubber disc wheel and, to our surprise, there was no disturbance such as is caused by a bursting band, and the gear did not open up. These gears are on so tight that they can just be moved in a sidewise direction with a heavy babbitt-hammer when the spider is well supported at the rim. To make sure that no side movement occurs, we put about three rivets through the spider with their heads overlapping the ring. It may be well to point out that the saving in this method is that we have reduced the weight of the high priced material enormously and we make the spiders of cast iron in our own foundry. The case that showed the reduced cost was in a bull gear which contained the differential. The differential spider was carried out to form the spider for the ring.

The volume of production makes a great difference in our specifying of steels, as was pointed out in the case of front axles. We find that certain steels are more easily cut in our machine shops. The relative order of production values that are generally conceded the alloys, seems to be chrome vanadium, plain chrome, plain nickel and chrome nickel in increasing order. This explains in some measure why our large-production automobile builders favor chrome vanadium, although it has a further so-called virtue of hardening satisfactorily over a wider range of temperature. We find production influencing our design in heat-treating, as well as in the machine shop. Parts are made for better group handling, as a job where we quench three a day by hand would swamp producers such as Ford, as they could not get or keep enough skilled men for this operation, aside from providing room for them.

Heat-Treating

We find in the S.A.E. Handbook specifications for heat-treatments of steels. To me these are vague and decidedly not specific and are good only for an indication of the treatment. The quenching medium cannot be placed in the specification because different sizes require different media and the proper drawing temperature has to be obtained from the designer's or heat-treater's experience. These specifications should not be taken too literally, as has been already pointed out.

In a general way, we find that annealing is used for (*a*) removing strains, as in cast iron cylinder heads; (*b*) softening material, as in old tools to be recut; and (*c*) to obtain a maximum refinement of grain, as in cast steel. We should use annealing before machining on all forgings of mild steel for grain refinement and the elimination of hard spots.

A preliminary heat-treatment should be given all alloy forgings or highly stressed parts or where distortion is objectionable. We all know that the object of quenching after machining is hardening. The subsequent draw may be to accomplish (*a*) toughness or (*b*) the removing of strains. We carburize for a hard surface and heat-treat for a tough core. For example, our knowledge is applied thus:

(1) Gears which carry little stress and little wear need no treatment when made of cast iron, mild steel or bronze
(2) Where we have a large amount of wear and light stresses, we use mild steel, carburized and treated by single or double quenching and then drawn
(3) For extreme wear and high stress we use alloy steel carburized and given a preliminary heat-treatment, double quench and draw
(4) For high stress and low wear, we use the alloy steels with preliminary heat-treatment, single oil quench and draw
(5) For extreme wear and stress, we may have to use a self-hardening alloy steel with even two preliminary heat-treatments and an oil or air quench and draw

We find special operations that accommodate design or production, such as copper-plating a piece on all surfaces to be left uncarburized, or we apply a supplementary operation after the pieces have cooled off in the carburizing boxes and before hardening, such as machining excess stock which carries a case from the carburizing operation. This leaves the material soft on desired surfaces, after the usual quenching or hardening treatment.

One further thing is the heat-treatment of manganese steel castings; all of these are quenched from about 1800 deg. fahr., in water. Before this operation the material is very hard and brittle. The control factor in production work is all-important and is a broad subject; it includes furnaces, temperature indicators and inspection guided by limits set by the engineering department.

THE DISCUSSION

A. H. Bates:—Mr. Moody spoke about a double quench and a draw for gears. We give many of our gears only one quench.

C. S. Moody:—The object of the double quench and the draw is simply to refine the gear further in the core. If two different kinds of steel are taken, we must quench them at different temperatures to get the maximum refinement in each. When we have a case-hardened gear, we have a surface of high-carbon steel on the outside and on the inside a mild-steel core. With the double quench we use a high temperature, probably 1550 or 1600 deg. fahr. for the first quench, to refine the internal part of the gear or the core. It also hardens the case, but it leaves the grain size in the case fairly coarse; so we give a second treatment. This is a quench from about 1350 to 1400 deg. fahr., possibly a little higher, depending on the steel; that refines the case and at the same time acts as a drawing operation on the core, toughening it. We can demonstrate that very easily if we take a mild-steel rod, carburize it, break it and give one piece a single quench and another a double quench, using the proper temperatures. One cannot bend the single-quenched rod, but can bend the second and fracture the case without having the fracture progress through the core.

Mr. Bates:—Is there not then more warpage? We had an instance in which we wished to change some hardened gears; in going over them again, drawing and quenching, we found there was considerable warpage.

Mr. Moody:—There is a tendency toward that. I do not know what your methods of fitting were. My opin-

ion is that no gears can be put into a tractor without being fitted; that is, machining the surfaces or grinding to fit the shaft. In other words, I prefer to have the machined surfaces finished after heat-treatment. If that is done, much more distortion can be allowed. For instance, with a light thin gear one is apt to get into difficulty with distortion; care must then be taken to eliminate it.

E. F. NORELIUS:—Has Mr. Moody had experience in the case-hardening of crankshafts?

MR. MOODY:—The case-hardening of crankshafts is new. I doubt very much if it really warrants the extra trouble it causes. It can be done. From what I have read I judge that the process can be simplified very much, getting the wearing surface where we want it. A considerable amount of work is necessary in this connection and the equipment must be much more extensive.

R. S. KINKEAD:—In a single treatment such as Mr. Bates referred to, the air is kept away from the part prior to and during quenching and, as a rule, the part comes out clean; but in reheating for a second quench the gas or air that comes into contact with the part oxidizes it and forms a scale that is wholly objectionable. We tried to overcome that objection in some of the smaller parts we have been making.

MR. MOODY:—I cannot say too much against the practice of quenching from the carburizing boxes; as the pieces are hot, the carburizing temperatures being about 1700 deg. fahr., an excessively large grain-size is produced and a brittle product is the result. If the pieces are large and can be quenched that way easily, it is all right and it is cheaper. Regarding the scale that occurs, as a matter of fact, our gears are cooled off in the boxes and reheated twice from the cooled state. That is to get the benefit of going through the critical range, refining the core, coming back up again and recrystallizing the case. The scale referred to is almost entirely under the control of the furnace operator. He generally uses three times as much air as is necessary. After about three years of effort I have trained my furnace operators to look for a "lazy" heat. We are not getting complete combustion because we have not enough oxygen. When we have an insufficient amount of oxygen we cannot get scale. Our operations provide for cleaning after the complete treatment is finished. We use a sand-blast with shot, and we can use the shot again and again.

MR. VALENTINE:—For a front axle on a 1000-lb. machine, would you use cast steel or a good malleable iron?

MR. MOODY:—I think it would not make much difference. I favor cast steel, particularly if a fairly good-sized production is expected. We get good results from malleable cast iron, but just as soon as we get on a production basis we have to examine all the axles for hardness.

L. F. NIELSEN:—Is there not some way other than the use of a sand-blast to eliminate the scale? What of the sulphuric-acid pickle?

MR. MOODY:—The sulphuric-acid pickle endangers the workmen; the acid also works into the steel. Research has proved that it leaves the steel more brittle than the other methods of cleaning. The process is dirty and messy and the acid must be washed off the parts with hot water. I think the process will be found to be much more expensive as well.

MR. NORELIUS:—As to the treating of hardened cast-steel, we have made a practice of subjecting drag-links, having approximately 0.35 per cent of carbon, to an oil-quenching treatment. What would Mr. Moody recommend?

MR. MOODY:—I have had to do many things with cast steel. We are water-quenching one particular gear coupling, followed by a low draw. I believe that anything can be done with cast steel that can be done with forged steel, within the limits I have mentioned. We generally give a double treatment; first, a quench from about 1600 deg. fahr. to break down the grain-size; second, a regular treatment, such as we would give forged steel. But there appears to be little call for heat-treated cast steel, aside from the tractor line. Tractor men seem to be the only ones who are doing any new work on cast steel.

MR. NORELIUS:—Do you quench in water and draw?

MR. MOODY:—Yes. Oil is all right, however; it all depends on what is desired. Sometimes we quench in oil because we do not want the product as hard as we get it with water, with the added danger of distortion.

MR. NIELSEN:—To what degree of hardness is it safe to draw cast-steel axles; for instance, the ordinary casting containing say 0.30 per cent carbon?

MR. MOODY:—Do you refer to a quenched or an air-cooled axle?

MR. NIELSEN:—A quenched axle.

MR. MOODY:—I do not know whether you desire strength or hardness but, ordinarily, in a cast-steel axle strength and considerable toughness are desired. We formerly used a temperature of about 1550 deg. fahr. and cooled in air; then we would draw at 1100 deg. fahr. and cool in air. A good example of what that will do is our experience with axles at about the time we became interested in smaller size tractors. We wanted a drop-forged axle but could not get it; we were forced to take cast steel and we performed the operation I have mentioned on the axle. But we had to have the steering-arm on the same machine also of cast steel. We were not concerned about that; so nothing was done with it. I have a distinct recollection of one of our 16-30 machines coming back after a railroad accident in which the car had been badly jammed. We found the wheel on the left-hand side was lying absolutely flat; in other words, the axle had been bent more than 90 deg. but the steering-arm on the end of that axle had been snapped right off straight. As to the hardness, that all depends on what strength is desired; only a certain strength can be attained at a given hardness. In any event hardness is variable when using cast steel, because it does not run so uniformly as a good forged steel. I do not know what your conditions are. I imagine a Brinell hardness of about 200 would give fair stiffness. That is about as far as one would dare to go with say 4.2-in. diameter. You might draw down as low as 650 deg. fahr. I think I would go no lower than that.

A MEMBER:—Do you use 0.30 per cent carbon steel or higher?

MR. MOODY:—We use steel having about 0.35 to 0.45 per cent of carbon. When it is quenched and drawn it goes to a 90,000-lb. maximum elastic limit. We have done something with that on some of our steering-arms, where we could not get a drop-forging, on our 20-35 machine, for instance, and have not had any trouble.

H. E. JOHNSON:—Has Mr. Moody had experience in testing various steels at different intervals? I have in mind the testing of steel balls. After a ball has gone through its heat-treating process, it is tested shortly subsequent to being finished. In testing $\frac{5}{8}$-in. steel balls the second or third day after they were considered finished, we could not get a greater crushing strength than approximately 12,000 lb. Two weeks later the same balls were tested again and we found that the crushing strength was as high as 28,000 lb.

MR. MOODY:—After work has been done on any piece of steel, a variation will be found between the time directly after the work was performed, and some time after that. When we were doing shell work, the only way certain companies could get their shells right was to let them lie on the radiator for a time and obtain the elongation in that way; they could not do it immediately after machining. There is some stress in the metal and the strains are equalizing themselves. If there are strains due to quenching or machining or anything like that, a part of the elastic limit is being absorbed. Any stresses applied after that can only make up the difference between what one has already used and the elastic limit. In the case of your example I would question the method of testing before I worried very much about a large variation like that.

MR. JOHNSON:—That range seemed very evident in exhaustive tests. We tested thousands of balls in that same manner.

MR. MOODY: — What heat-treatment are you giving them?

MR. JOHNSON:—One operation is that of quenching in boiling water, which seems to give far better results.

MR. MOODY:—Do they do any drawing back on that?

MR. JOHNSON:—I think they do.

MR. MOODY:—Unless they did this, there would be apt to be strains in the balls. It would take some time to neutralize such strains by aging in air.

IS LUBRICATION A CHEMICAL PHENOMENON?

THE common popular view regarding the action of a lubricant is based on the belief that friction is produced by the roughness of the contacting surfaces. The lubricant, it is supposed, fills up the roughness, and in the layer of it between the surfaces provides a series of molecular balls that acts after the manner of a ball bearing. This theory may be crude and readily open to scientific refutation, but so long as we do not push it too far it is fairly satisfactory. Further, if we associate the conception of the ball-bearing action of the molecules of the lubricant with the property of fluids that we call their viscosity, the theory reflects the importance that, in practice, is attached to the viscosity of lubricating bodies. This hypothesis is, at best, only tenable when we assume that we are dealing with fully lubricated bearings; that is to say, bearings in which the two surfaces are definitely floated apart on a film of lubricant of material thickness. In such a condition the fluid substitutes its own internal friction, or viscosity, for that of the one clean metal on the other, but between the viscous friction of completely lubricated surfaces and the dry friction of completely unlubricated surfaces there is an intermediate condition described, perhaps a little unfortunately, as the greasy friction of partially lubricated surfaces.

Crudely speaking, we may say that in partially lubricated bearings there is no interposing film of fluid between the surfaces, that the surfaces are in contact, and that the lubricant is present, at most, only to the extent required to fill up the roughness. This oily condition can be produced by wetting a clean surface with lubricant and then wiping it. Lord Rayleigh, it may be remarked, studied the greasy state by glass plates smeared with the fingers after they had touched the hair. It is not, we think, a matter for surprise that the laws of viscous, greasy and dry friction should be found to be radically different. In dry friction the coefficient varies with the material of the contacting surfaces and their state of preparation. In the case of viscous friction the coefficient is hardly affected by the nature and condition of the surfaces, but varies primarily with the lubricant used. Turning to greasy friction, we find that the coefficient, according to R. M. Deeley's experimental results, varies both with the nature of the surfaces and with the lubricant used. The significance of this statement can be illustrated by a specific example. As a means of reducing friction between mild steel and cast iron, olive oil and rape oil tied for first place out of 11 different oils tested, while castor oil and Manchester spindle-oil tied for fourth place. But when the oils were tested between mild steel and gun-metal the order of merit was very different. Rape oil again occupied first place, but olive oil fell to the fifth. Castor oil moved up to the third position, but Manchester spindle-oil fell to the ninth. The lubricating value of an oil in a partially lubricated bearing, if these results can be accepted, does not, therefore, depend solely on the oil, but is largely determined by the precise metals of which the surfaces in contact are composed. From these observations Mr. Deeley has been led to the belief that the oil film in partially lubricated bearings is not oil per se, but is actually a compound formed by the oil with the metal. The compound is in his opinion not a mere mixture or interlacing of the molecules but a definite union attributable to the action of interatomic forces. In other words, it completely and exactly fulfills our conception of a chemical compound, and in our opinion can, in the case of a fatty lubricating oil, be conveniently referred to for the purpose of discussion as oleate of iron, copper, cupro-tin, etc. In this connection it is to be noted that common soap is formed by the union of fatty acids with sodium or potassium. The alkali can, however, be replaced by various other metals. Thus "soaps" formed by the union of fatty acids with iron, nickel, cobalt, zinc, magnesium, aluminum, copper or mercury are possible, and are actually made and used for a wide range of industrial purposes. The suggested union of the oily molecules with the molecules of the contacting surfaces in a partially lubricated bearing is thus not a chemical absurdity so long as we confine ourselves to animal or vegetable oils. In the case of mineral lubricating oils, however, the nature of the suggested compound is less readily pictured, although it is possible, by Mr. Deeley's theory, to propound an explanation of the facts reported by Messrs. Wells and Southcombe in support of their "germ" theory regarding the addition of small quantities of free fatty acid to mineral lubricating oils.

It may be true, as stated in the report of the Lubricants Inquiry Committee, that "at the present time only a comparatively small number of bearings and rubbing surfaces are working under conditions of complete lubrication, and that an immense majority are working either wholly or in part as partially lubricated surfaces." Still, the fact remains that the partially lubricated bearing is hardly more efficient than a dry bearing and should be avoided in practice. The exact laws governing partial lubrication can, therefore, have little direct practical application. At the same time we recognize that if chemical action is at the basis of partial lubrication it must also enter in some degree into complete lubrication, and that such a revolutionary belief could not be established without affecting our whole outlook on all the problems of lubrication.—*The Engineer* (London).

Important Factors in Piston-Ring Design

By H. H. Platt[1]

Washington Section Paper *Illustrated with* Diagram

THE purpose of piston-rings in an internal-combustion engine is to reduce to a minimum the leakage of gas from and the seepage of oil into the combustion-chamber. Asserting that the widely held idea that the leakage of gas past the piston can be eliminated by the use of good piston-rings is incorrect, the author states three possible paths for such gas-leakage and, after commenting upon them, discusses diagonal and lap joints and the subject of leakage with special reference to them.

After considering the design of rings for gas-tightness, the author shows a fortunate mathematical relationship, in connection with the application of uniform radial pressures, regarding the bending-moment stresses. Oil leakage is treated in a similar manner and the conclusion is reached that the properties of the material used are of extreme importance.

THE purpose of piston-rings in an internal-combustion engine is to reduce to a minimum the leakage of gas from and the seepage of oil into the combustion-chamber. There seems to be a widely held notion that the leakage of gas past the piston can be eliminated entirely by the use of good piston-rings. That this is not the case can be demonstrated by removing the crankcase cover from a warm engine and noting the bubbling and hissing of the escaping gas when the engine is turned over slowly; the exact volume of gas leaking past the pistons of an operating engine can be measured better by closing all openings from the crankcase except one, which is connected by a pipe to a calibrated gas-collector. Precautions must be taken to maintain the pressure and temperature of the collected gas at as nearly atmospheric conditions as possible. Knowing the piston displacement, we can easily write the leakage as an approximate percentage of the air passing into the engine at full load. Extremely good values for the leakage at full load are 2 per cent at 400 r.p.m. and 0.5 per cent at 1600 r.p.m. With poorly designed piston-rings these values are many times greater. Evidently, then, the loss of power due to piston leakage is never negligible, although it can be reduced to a value that is small in comparison with other sources of power loss.

There are three possible paths for the leakage of gas past a piston-ring. Putting the least important first, these are (*a*) through the gap, (*b*) around the back of the ring and (*c*) past the face. It has long been known that the gain in power resulting from attempts to seal the joint has been insignificant, and that in many cases there has been an actual loss. The reasons for this failure in practice have apparently never been clearly set forth.

The rate of leakage through an aperture is approximately proportional to the area. The smallest sections of the path through the gap are those at the entrance to and the exit from the gap. The section at each of these points is a nearly rectangular orifice bounded by the cylinder wall, the piston surface and the ends of the ring. The maximum area of this opening is the piston clearance multiplied by the clearance between the ends of the ring. Under operating conditions, for a medium-sized cylinder, these values should not exceed 0.004 and 0.005 in. respectively. The area of the aperture is then $0.004 \times 0.005 = 0.00002$ sq. in.

Suppose that for a portion of its circumference the ring fails to make full contact with the cylinder-wall or with the side of the groove in the piston. Then the area of the crack exposed to leakage is equal to the product of its length and its average width. A very slight inaccuracy would give rise to an opening having a length of 1 in. and an average width of 0.0002 in. The area of such an opening is 0.0002 sq. in. and, if we assume an aperture of this size for each leakage path, the total area is 0.0004 sq. in. or 20 times the gap area calculated above. It is plain, therefore, that the advantage of stopping the joint leakage cannot be expected to balance the inaccuracy introduced by the complicated construction necessary to accomplish that end. This conclusion can be confirmed by observing the distribution of the bubbles of escaping gas around a piston equipped with plain-jointed rings. No preponderance in the neighborhood of the gap will be noticeable. Thus we are brought to the necessity of deciding between the two simple types of joint, the diagonal and the lap.

Diagonal and Lap Joints

The only possible advantage of the lap joint is reduction of gap leakage. The idea that it has any appreciable effect in this direction is utterly fallacious. The gas leaking through the small orifice at the entrance to the gap passes directly into the comparatively large space in the groove back of the ring, which connects directly with a small orifice at the exit from the gap. The leakage path past a lap joint consists, therefore, of three portions; these are a restricted entrance, a large central passage and a restricted exit. The same thing is true of the path through a diagonal joint, and the area of the restricted orifice, which is the only area that counts, is the same for each case.

The diagonal joint, on the other hand, has four definite advantages. First, the points are free from the danger of breaking off, which is noticeable in the lap joint. Second, a dull cutter leaves a fillet in the corner of the lap joint. The opposite sharp point rides on this fillet, thus reducing the effective clearance in the gap and, in extreme cases, causing cylinder scoring. The diagonal joint is not subject to this trouble. Third, the gas impinging on the diagonal face of the end of the ring has a definite slight tendency to cause the ring to creep around in the cylinder, thus insuring even seating both on the cylinder and in the groove. Moreover, if the diagonal cuts are made and installed alternately right and left

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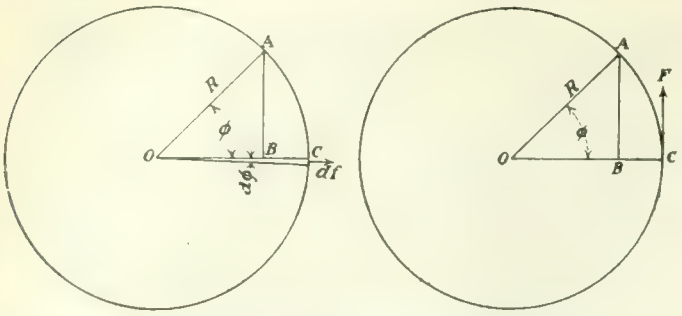


FIG. 1—DIAGRAM SHOWING THE RELATION OF THE FORCES ACTING UPON A SPLIT PISTON-RING

handed, the creeping is in opposite directions for alternate rings and all the gaps cannot stay in line. Fourth, and probably most important, the simplicity of setting and holding for the plain diagonal cut insures greater accuracy. In reducing the leakage around the back of the ring, accuracy in machining both the ring and the groove is of paramount importance. Other desiderata are freedom from warping and maximum width of contact between the ring and the groove.

It is usually supposed that no leakage can occur past the face of a ring that has a complete circumferential bearing. A little consideration will show that this supposition is incorrect. Between the ring and the cylinder surface there exists a film of oil which prevents actual metal-to-metal contact. The thickness of this oil-film depends upon the body of the lubricant, the smoothness of the surfaces and the pressure per unit area. The oil is held in place only by capillarity and viscosity. The sum of these retaining forces in the case of the lubricants and surface pressures available in practice is never equal to the displacing force of the high pressure in the combustion-chamber. Consequently, some of the oil is blown out of the film space and some gas follows it. This conclusion has been verified by leakage tests in which rings of varying pressure, otherwise exactly similar, were compared. Leakage invariably increased with a reduction in the surface pressure. These results would point to an advantage in giving the pressure a maximum value. Increasing the pressure, however, increases the friction loss correspondingly and a point is soon reached where the gain is entirely offset. The pressure that produces a combined minimum power-loss varies greatly for different designs of engine and for different classes of work. When a very high surface pressure is desired, it can be obtained by relieving a portion of the face of the ring with oil-grooves and the like. This practice is not generally recommended, however, on account of the more rapid wear of the ring and the cylinder.

DESIGNING RINGS FOR GAS-TIGHTNESS

If a ring presses against the cylinder-wall with the same pressure at every point of its circumference, the oil-film will be of uniform thickness. If, however, there is a variation in the pressure at different points, the oil-film and the leakage space will be greater at some points than at others. It is evident, therefore, that the total leakage past the face of a ring is considerably increased by uneven surface pressure. The actual saving resulting from careful attention to this point is even greater than one would suppose possible. In an impartial test rings made by a process that produces approximately uniform pressure were compared with several other makes less accurate in this respect. All rings were made to the same specifications and all were light-tight in a standard gage. The uniform-pressure ring allowed the passage of one-third less gas than did its closest competitor.

The most important factor in designing for gas-tightness is, therefore, the development of a process for imparting to a ring the property of exerting uniform radial pressure against a round cylinder. It is easy to show by a simple analogy that, to meet this requirement, the ring must have a very definite shape. If we apply uniform downward loading to a straight cantilever beam it will deflect in the form of a parabola. If the beam were set in the parabolic form and the loading removed, it could be brought back into straight-line form only by the application of uniform upward loading equal in value to the original downward pressure; that is, if a flat horizontal surface were pressed upward against the beam, the pressure against that surface would be uniform throughout the length of the beam. The two halves of a piston-ring can be considered as cantilever beams fixed at the point opposite the split. Evidently, then, if we expand a split tensionless ring by the application of uniform outward radial forces, each half takes on a definite shape which bears a relation to a semicircle similar to that of the parabola to a straight line. If the ring is set in this shape and the load removed, it is evident that it can be compressed into its original circular form only by the application of forces exactly equal and opposite to those by which it was originally expanded; that is, by uniform radial inward forces. Therefore, when placed in a true cylinder of correct diameter, the forces acting between the ring and the cylinder must be uniform around the entire circumference.

The application of uniform radial pressures would present serious practical difficulties if it were not for a very fortunate mathematical relationship. At the left of Fig. 1 a split ring is shown, of radius R, with the split at the point C. Assuming that the ring is acted on by uniform radial expanding forces whose intensity is f weight units per unit length of arc, and that $\partial\phi$ is an indefinitely small angle, then

$$\partial f = fR\,\partial\phi$$

where ∂f is the radial force acting on the arc subtended by the angle $\partial\phi$.

If the bending-moment at any point A, removed from C by the angle ϕ due to the force ∂f is ∂m.

$$\partial m = \partial f \times AB$$

where AB is the perpendicular distance between A and the line of the force ∂f.

But

$$AB = R\sin\phi$$

Substituting,

$$\partial m = fR^2\sin\phi\,\partial\phi$$

The total bending-moment at A equals the summation of the moments resulting from all the forces between C and A. Using M to represent the total moment at A,

$$M = \int_0^{\phi} \partial m \cdots \int_0^{\phi} fR^2\sin\phi\,\partial\phi$$

Integrating and simplifying,

$$M = fR^2(1 - \cos\phi)$$

At the right of Fig. 1 the same ring is shown, but it is acted on at C by a tangential force F. The bending-moment M, at the point A is written

$$M_1 = F \times BC$$

where BC is the perpendicular distance between A and the line of F.

$$BC = R - OB$$

and

$$OB = R\cos\phi$$

Therefore

$$M_1 = FR(1 - \cos\phi)$$

Comparing this equation with the formula for M, we see that $M = M_1$ when $F = fR$.

The bending-moment stresses produced by uniform radial expanding forces are, therefore, identical at every point with those caused by tangential forces of the proper value applied at the split. Since the curvature at every point depends only on the bending-moment stresses, tangential forces applied at the split produce an expanded ring having exactly the same shape as that resulting from uniform radial forces. Therefore, to produce a ring of the correct form we need merely pull the joint apart, insert a spacing piece and subject the expanded ring to a sufficiently high temperature to release all internal stresses. It should be noted that the mathematical relation is independent of the shape of the section and of the actual values of the stresses at any point. Consequently, variations in thickness and in quality of material have no effect on the property of radial uniformity of pressure.

The practical application of this method introduces minor difficulties and inaccuracies that need not be set forth in detail here. The difficulties have been overcome successfully and the inaccuracies, very small in the first place, fortunately happen to counteract each other; so, even in quantity production, the rings show astonishingly small variation from the correct shape. These rings are accurately ground before splitting and are not refinished after the shaping process. Therefore, they possess a distinctive blue-black coating of iron oxide. The finished rings are tested for accuracy by the light test, and practically 100 per cent pass it; also by the ring-gage test which has been modified to make it easier of application. The ring is forced into the proper ring-gage, the ends are clamped together and it is then withdrawn. Evidently when freed, the points at which the pressure against the gage is greatest spring outward, causing the ring to assume a slightly non-circular shape. The deviation from circularity, measured with micrometer calipers, is an indication of the uniformity of the radial pressure. The majority of the rings are so nearly round that the deviation is not measurable. The greatest difference between the maximum and minimum diameters is not allowed to exceed 0.005 in. Other makes of ring usually show at least three times this discrepancy.

Oil Leakage

The chief requirements for preventing excessive oil-leakage are the same as those for gas tightness. In addition, it is of great importance to reduce to the minimum the volume of the space in the groove not occupied by ring material. Any such space acts as a first-class oil-pump and tends to fill with oil at the bottom of the stroke, where the conditions are those of suction and abundance of oil, and to empty at the top of the stroke when the oil is driven from the space by high-pressure gas. This fact eliminates the eccentric ring from serious competition and makes it important that the concentric ring should fill the groove as completely as safety permits.

Two important relations can be derived from the foregoing mathematics. It can be shown easily that

$$p = F \div wR$$

where

F = tangential force applied at the gap necessary to compress the ring to the cylinder size
p = pressure per unit area
R = radius
w = width of face

This tangential force is approximately one-half the more easily measured force which, when applied normally at a point 90 deg. from the gap, closes the ring to the cylinder diameter. The most satisfactory general-purpose pressure is thus found to be between 8 and 10 lb. per sq. in.

The second relation is an equation for ascertaining the maximum working unit-stress on the material of the ring. Applying the ordinary beam formula we find that

$$S = 12FR/wt^2$$

where

S = maximum unit-stress
t = thickness of the ring at the point opposite the split

Written in terms of surface pressure this equation becomes

$$S = 12p(R/t)^2$$

This formula gives, for a ring of suitable dimensions having a surface pressure of 10 lb. per sq. in., a maximum stress of about 30,000 lb. per sq. in., which is undoubtedly somewhat above the actual value because of the deviation of cast iron from the condition of perfect elasticity upon which the beam formula is based. Nevertheless it serves to show that the working stresses in piston-rings are very close to the safe limit and much greater than those used in any other cast-iron part. The failure of many piston-rings is certainly due to the use of excessive stresses.

In determining the most suitable gap-opening we must consider the stress produced by forcing the ring over the piston. Obviously, breakage or serious distortion will result if this stress exceeds a safe value. On the other hand, the use of a wide gap to reduce this danger increases the working stress. The best opening is, therefore, one that nearly equalizes the two types of stress; that is, a gap that measures circumferentially about four times the thickness of a concentric ring.

These considerations make it evident that the properties of the material used are of extreme importance. If the iron is soft, of open grain and has a low modulus of elasticity, the requisite pressure cannot be obtained without excessive working stress. On the other hand, if the iron is very hard, close grained and possesses a high modulus of elasticity, a gap large enough to allow safe springing over the piston gives rise to too high surface pressure and working stress. Moreover, if the ring material is much harder than that of the cylinder, excessive wear results. The degree of hardness in iron castings increases with the rapidity of cooling; therefore, the smaller the section of the casting, the harder the material should be. We have found that small individual castings have too small a section for the best results, while long-pot castings are entirely too soft. We have, therefore, developed a short-pot method in which castings about 2 in. long are used. The properties obtained in this way afford a very satisfactory compromise between the two extremes.

THE DISCUSSION

F. Davis:—I understand that the ring is heated to a certain temperature when expanded. What is that temperature?

H. H. Platt:—We have found 1200 deg. fahr. a satisfactory temperature, but a considerable range could be used.

Mr. Davis:—Does not the structure of cast iron change at 1200 to 1250 deg. fahr.?

Mr. Platt:—We find no appreciable change due to heating cast iron to 1200 deg. fahr. At temperatures considerably higher changes do occur.

MR. DAVIS:—Is there not a tendency to form temper carbon which affects lubrication?

MR. PLATT:—We have found no such effect. At temperatures somewhat higher than those we use we have found an actual increase in graphitic carbon, which would indicate improved lubricating qualities. Commercial chemical analyses, however, are not able to detect any difference between our treated and untreated materials.

MR. DAVIS:—Does not a piston-ring so treated tend to lose its tension when subjected to heat in the cylinder?

MR. PLATT:—A leakage test was conducted by the Cadillac Motor Car Co., under identical conditions, of five types of ring at various speeds, all at full load. The results are summarized in the form of performance percentages, the performance of a ring listed as a Cadillac being arbitrarily assumed as 100. These figures are as follows:

LEAKAGE TEST OF PISTON-RINGS

Ring	Percentage
Standard	100.0
Pedrick (heat-treated)	133.0
No. 3131	105.0
No. 2830	45.4
No. 2829	67.8

Also, actual leakage in cubic feet per hour is given for various speeds from 800 to 2000 r.p.m. Here we find the respective leakages at 800 r.p.m. for the heat-treated Pedrick ring and ring No. 3131 to be 58 and 56; they are almost identical. At higher speeds, however, we find ring No. 3131 falling off in comparison until, at 2000 r.p.m., the figures are 55.7 and 96.0 respectively. The heat-treated ring is the only one in the entire list that shows less leakage at 2000 than at 800 r.p.m. This is certainly strong evidence against any theory to the effect that these rings lose tension under severe service. Ring No. 3131 is described as a lap-joint, peened concentric ring; the make is not stated.

Another test referred to is one described in a paper[1] by A. L. Nelson entitled Fuel Problem in Relation to Engineering Viewpoint. In this test the engine was run under very severe conditions a number of times without any let-down in performance. Heat-treated Pedrick rings were used in this test. We have had no complaints about loss of tension; indeed, we have been told by garage-men of rings that have run for more than 100,000 miles and are still retaining the complete original tension.

MR. DAVIS:—Has any difficulty been experienced in the use of such rings in motorcycle engines, where the service is more severe than in the average automobile engine?

MR. PLATT:—We have had no trouble with such use. One of our oldest users is a motorcycle manufacturer.

MR. DAVIS:—Has any test been made to determine the evenness of wear of rings so made?

MR. PLATT:—We have tried rubbing rings up and down in a cylinder. The wear appeared to be even.

MR. DAVIS:—Would not a light-tight ring also do this?

MR. PLATT:—If the pressure were uneven, a difference in the bearing would be noted at different points.

H. S. MCDEWELL:—Have you made any device for measuring radial pressure accurately?

MR. PLATT:—No device of this kind that I have seen is capable of differentiating between inequalities of pressure due to inaccuracies in machining, which soon wear off, and inequalities due to incorrect shape, which are permanent.

MR. MCDEWELL:—What do you estimate that a deviation from roundness of 0.005 in. means in actual figures of pounds per square inch in the test that you described?

MR. PLATT:—I have made no attempt to determine the actual values. Our tests have been comparative only.

C. W. TUCKER:—Should rings be closed? What do you allow for the sawcut when grinding oversize?

MR. PLATT:—We use a 1/32-in. saw and allow about 0.010 in. oversize to close the sawcut to the proper end-clearance.

MR. TUCKER:—What is a reasonable end-clearance for a ring? Would there be danger of scoring if it were kept down to 0.002 in.?

MR. PLATT:—A reasonable end-clearance for a medium-sized automobile engine is 0.005 in. There would be danger of scoring if 0.002-in. end-clearance were used. We find great difference of opinion on this point, however.

MR. MCDEWELL:—Do you find that heat-treated rings require less clearance than other rings?

MR. PLATT:—We have found no difference.

MR. TUCKER:—Is there any rule for the clearance between a ring and the bottom of the groove?

MR. PLATT:—That depends upon conditions, such as the size of the ring and the cylinder. We have found 0.01 in. to be a good general rule.

A. W. MORTON:—Do you find it necessary to return or regrind the rings after cutting them?

MR. PLATT:—No. An interesting point is that we tried both methods and found that the refinished rings were actually less accurate than those finished before splitting.

MR. DAVIS:—A section of a ring 2 in. long has a certain form when ground oversize. Does this shape change when a spacer is inserted at the ends and the ring is subjected to heat-treatment?

MR. PLATT:—The original ring is circular. No part of the finished ring is circular.

MR. MORTON:—Is one tension advisable for all sizes of rings?

MR. PLATT:—In our standard rings we use the same working stress for all sizes and the same surface pressure. In making rings for manufacturers who furnish their own specifications, we meet those specifications without question on the assumption that the manufacturer is better fitted to prescribe for his special condition than we are.

W. M. WALLACE:—In the May, 1921, issue of THE JOURNAL there is printed a short discussion[2] I made of A. L. Nelson's paper in which attention is drawn to certain major features of design that seemed to have been overlooked by engine designers generally. The matter of fuel economy in the millions of existing engines, coupled with the poor grade of fuel at present obtainable, indicates the importance of the greatest possible effort by all interested to solve the perplexing question in a practical and unselfish manner. If we must change our ideas completely, it should be done as promptly as the soundness of the premise is established.

I have followed the trend of piston design in a general way for many years, because it seemed to me that the ultimate success of the design would be measured in this one part almost wholly. I regard the piston as the most important single part of any engine. It receives at first hand all of the work that comes from the combustion-chamber. Its success or failure is measured in thousandths of an inch. Failure to be tight and keep tight invites loss of fuel with all its attendant difficulties. It is difficult to lubricate properly and over-lubrication is a constant source of vexation and expense. The piston is a

[1] See THE JOURNAL, February, 1921, p. 161.

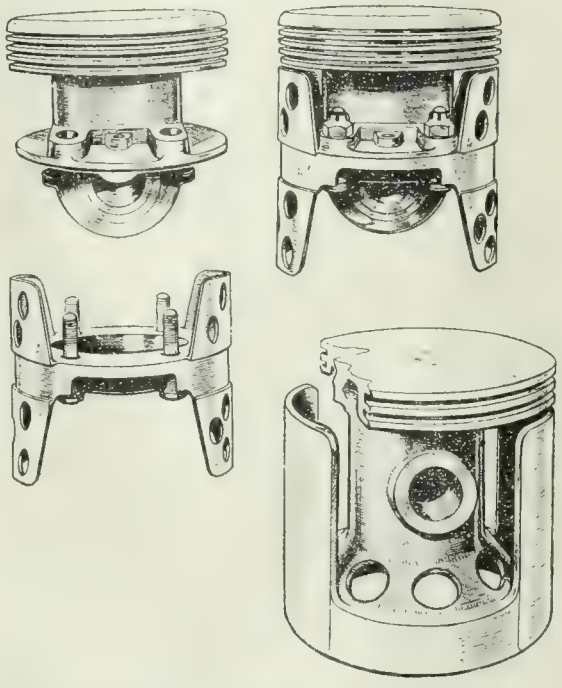
[2] See THE JOURNAL, May, 1921, p. 458.

possible source of great friction. A piston can be made tight when new with almost any kind of ring, the piston itself embodying almost any kind of novelty in design to suit the fancy of the designer. Pistons can be made of various materials and of various shapes. In the beginning, when the materials distort after they become hot, we can apply corrective measures, but to keep pistons tight they must be proof against undue wear and subject to adequate lubrication. This requires the use of proper material for the purpose, and design such that the bearing pressures will be uniform, thereby permitting efficient lubrication, reducing wear and keeping the crankcase clear of its great enemy, free gasoline.

Some take the view that the millions of engines now in use cannot cope with present gasoline conditions. This view is wrong from all angles. Hardly an engine is in existence to-day with a poorly designed piston that is not capable of further good service if provided with a new and specially designed piston that is interchangeable with the old one. Each engine presents problems of its own, but slight research in each case, intelligently applied, will solve the problem to the extent of showing great improvement. Having provided good substitutes for poorly designed pistons, let them be put at once into production, inclusive of parts stock. In this way, in an astonishingly short time, not only will the reputations of the makers be enhanced, but good service will be reported from older models that have been rehabilitated.

Developments in Piston Design

IN addition to their efforts to raise combustion and carburetion efficiency, it is evident that British automotive engineers have given no little thought to the matter of mechanical losses. In their analysis of engine performance several of the authorities have concluded that steps can be taken to increase the mechanical efficiency of high-speed internal-combustion engines by certain design modifications. In a report on airplane engine efficiencies Dr. A. H. Gibson presents data that show the effect of piston friction on brake mean effective pressure and emphasize the importance of this loss when an increase in overall engine efficiency is attempted. Harry Ricardo also has worked on the solution of the problem of reducing piston friction and evolved the interesting design shown at the left of the accompanying illustration. In this piston aluminum is employed as the material for the head in view of its high heat conductivity and light weight. The skirt or slipper is made of cast iron which in addition to its proved value as a skirt material has the advantage of a lesser coefficient of expansion and can be fitted to the cylinder with a minimum clearance. The lack of a direct path for heat travel to the skirt and the fact that most of the heat is conducted through the rings to the cylinder-walls should still further reduce any chance of seizing. The elimination of all slipper surface that is not of direct value in carrying the piston side-pressure should reduce friction to a minimum and decrease the work lost in shearing a large oil-film. Judging from the illustration, the design is also attractive from the production engineer's viewpoint.



TWO PISTONS THAT HAVE BEEN DEVELOPED IN ENGLAND RECENTLY

The Single-Piece Piston in the Lower Right Corner Was Produced by Vauxhall Motors, and the Two-Piece Piston That Is Shown Assembled in the Upper Right Corner and Separated into Its Component Parts at the Left Was Designed by Ricardo

Another design equally interesting was evolved by C. E. King of the Vauxhall Motors, Ltd., and is shown in the view at the right. In this type the piston is a single unit cast of one material. Frictional losses are minimized as in the Ricardo design by eliminating all skirt surface not directly useful for thrust purposes. The cantilever construction of the slipper faces no doubt allows considerable flexure and consequent reduction of side-play. It is the designer's theory that the interior cylindrical trunk and the perforated conical flange will transfer to the lubricating oil the greater portion of the heat not lost through the rings to the jacket water and in this way minimize the expansion and contraction of that part of the piston which fits the cylinder bore. This should reduce chance of piston slap and the required clearance of the piston in the cylinder.

The Future of Road-Transport[1]

By Lord Montagu of Beaulieu

A BRIEF review of road-transport conditions in the last 100 years shows how the roads went out of use on the advent of the railroad, and how they have come into use again with the development of the motor car. To-day mechanical road-transport has to face three important problems: (*a*) how the permanent way is to be made and paid for; (*b*) how the fuel is to be secured at reasonable prices, and, (*c*) how commercial road traffic is to be controlled and organized.

While due credit must be given for the work done to the roads in the last 10 years, it cannot be said that even the first-class roads of Great Britain are adequate for present traffic, and it is certain that in a few years they will be totally inadequate for the traffic they will have to carry. As to the second-class roads, they are as a whole unfit to bear much mechanical traffic. The present system of road-making is still comparatively temporary in its nature, and annual upkeep is therefore expensive from a rating and taxing point of view. In fact roadmakers are as yet only tinkering at the problem. They have inherited an obsolete system of making roads designed for one kind of usage and now used in a different fashion. They are attempting to live largely on the practice of the past and "to make the clothes of the child fit the man." It is difficult and expensive to make the tracks of the past, originally designed for slow horse-traffic at 8 to 10 m.p.h. with their bad engineering and dangerous corners, suitable for the high-speed mechanical traffic of today or of the future. Again, they are trying to make roads with a surface to suit all kinds of traffic. What is the result? Horse owners justly complain that their animals cannot stand up on asphalt surfaces on a frosty morning, the owner of the pneumatic tire car grouses legitimately at the sharp granite flints or unrolled metal that cuts his tires, and the roadside dweller, market gardener, and the user of the small class of horsed vehicles declare that the main roads have become unattractive owing to the heavy, fast, long-distance traffic, while cottagers complain that their children cannot safely play at the roadside.

Trunk roads, for the new traffic only, must be made between various busy centers, such as London, Birmingham and Manchester. It is unwise, unscientific and uneconomical to try to make the eminently unsuitable become the suitable. Special roads must be made all over the country, and on these mechanical transport should run free from speed limits. If the present speed limits are to be enforced, in a few years the police force will have to be doubled and trebled only for the purpose of keeping heavy traffic down to the speed of the governess cart and the passenger traffic to the speed of a good man-propelled bicycle. The roads, within reason, must be made to fit the traffic, and not the traffic the roads. While, of course, there must be regulations, especially governing speed and weight, the provision of bypass roads avoiding towns will dispense with the reason underlying the wise and inevitable limit in narrow streets. Bypass roads will save time and avoid danger. Many fundamental laws underlying railroad traffic can be applied as they stand to road traffic. As to passenger traffic, there is little doubt that in the near future at holiday times we shall see advertisements of such and such a line of passenger coaches leaving all the principal towns for destinations up to 200 or 300 miles distant, and with such developments large and good roadside hotels must also come.

Heavy motor vehicles will tend to run more and more by night, not only because of the clearer road but because the start at the end of one day and the arrival at the beginning of the next will be found convenient. The transport that conveys goods from a factory to the ship's side without any intermediate handling must come into increasing use. Broadly speaking, in such cases it is difficult, if not impossible, for a railroad to operate in the same time and with the same ease, partly because of the many handlings, and partly owing to the low speed of the average freight train. Door-to-door delivery by road-transport taking less time and costing less is the secret of its growing popularity. Mechanically, the rail holds the advantage, for it requires only one-third of the power to move the same tonnage on it as a well-made road. Yet in the last 20 years, while the labor cost has increased enormously, power has become relatively cheaper, and will become cheaper still. The greater power required for road-transport is therefore more than balanced. Often, for instance, a railroad involves eight handlings in the delivery of the goods from town to country against two by road.

The railroad future, therefore, seems to lie in really fast trains, averaging over 50 m.p.h.; heavy traffic in bulk, such as coal and iron; and at holiday times full trains between towns not more than 2 or 3 hr. apart, for passengers are self-sorting and self-handling freight. On the other hand, it is likely that much short-distance traffic up to, say, 100 miles, most cross-country traffic and a large proportion of the first-class traffic existing prior to the increase in railroad fares, will tend more and more to the road. Railroads already feel the draft in passenger and freight traffic, and the falling off in passenger traffic will continue and emptier trains will go on showing the effect of road competition combined with high fares.

The railroad era should be regarded only as a stage in transport development, and not as a permanent condition of affairs: the road era has just begun, and roads soon may be made of some permanent or "semi-permanent" material involving a negligible cost for upkeep. Speed limits will be abolished before long, at any rate on the open road, and when special motor-traffic roads are made the average speeds of passenger cars will equal, if not exceed, the average railroad passenger speeds. Railroads will be forced by competition into providing motor roads and conducting traffic by road as well as by rail. Some lines may be replaced by permanent roads. Overhead and underground roads are bound to be made in great cities, the streets of which cannot possibly carry the traffic, of even a few years hence, for to widen these streets is architecturally difficult and costly.

[1] From a paper read before the Institute of Transport (London).

Non-Injurious Ultimate-Strength Tests for Interplane Struts

By E. R. MAURER[1]

Illustrated with PHOTOGRAPHS AND CHARTS

THE two tests described are based on well-known theory and have been verified at the Forest Products Laboratory by experiment on solid struts of Sitka spruce and Douglas fir of the sections used in J-1 and DH-4 airplanes; also, to a lesser degree, on built-up veneer-covered struts and three-piece laminated hollow spruce struts. The slenderness ratio L/r for these struts ranged from 120 to 225. The first method is direct; the strut is subjected to an ordinary test for maximum load. The second method is indirect; the strut is subjected to a simple bending test to obtain certain data, which are used to calculate the ultimate strength.

The two methods are described in considerable detail inclusive of photographs, charts and a mathematical analysis of the second method. The verification of method by actual trials and the meaning of slender or Euler-class struts are described and explained, followed by a description of some simple homemade strut-testing machines.

THE object of this paper is to direct attention to two strength tests for ascertaining the carrying-capacity of airplane struts. These tests do not injure the struts, are reliable and practical, and are based on a simple and well-known theory. They have been thoroughly verified at the Forest Products Laboratory of the United States Forest Service at Madison, Wis., by experiment on solid struts of Sitka spruce and Douglas fir of the sizes used in J-1 and DH-4 airplanes, and to a lesser extent on built-up veneer-covered struts and three-piece laminated hollow spruce struts. The slenderness ratio L/r for these struts ranged from 120 to 225.

A random lot of airplane wood of any species probably varies widely in strength properties; even carefully selected lots have been found to vary greatly in strength. As examples, there are cited below 10 lots of airplane struts with their minimum and maximum breaking-strengths. These are all the lots recently tested at the Forest Products Laboratory and have been officially accepted for use in Army airplanes. Each lot was made by a single manufacturer.

Lot Number	Number of Struts	Material	Breaking-Strength, lb. Minimum	Maximum
1	20	Sitka Spruce	925	1,510
2	20	Sitka Spruce	1,610	3,055
3	11	Sitka Spruce	2,020	3,730
4	9	Sitka Spruce	3,780	5,760
5	6	Sitka Spruce	3,225	4,800
6	6	Douglas Fir	3,900	4,525
7	10	Douglas Fir	2,850	5,700
8	20	Sitka Spruce	3,880	6,250
9	11	Sitka Spruce	1,375	2,315
10	4	Douglas Fir	1,380	2,095

To provide adequately against the inferior pieces of wood that might enter into construction, the airplane engineer must design with appropriately low working stresses. The result is, of course, a heavier airplane and one which is far from being equally strong in all its parts. The ideal light and uniformly strong plane cannot be attained practically, but a long step toward it can be taken with reference to wood interplane struts by employing one of the two strength tests described on each finished strut to supplement the customary inspection for moisture, density, grain and defects. Under this plan the engineer would design with higher working stresses and depend on the additional test to insure the strength counted upon by him in his design.

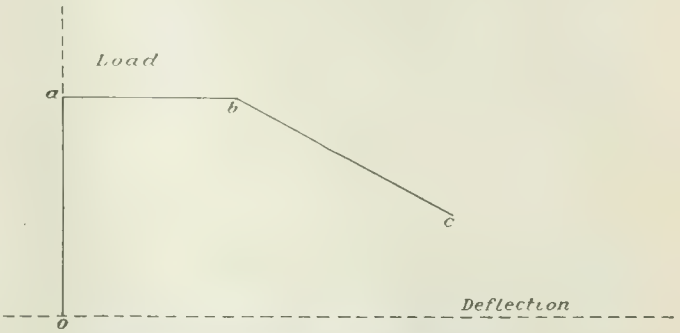


FIG. 1—DIAGRAM ILLUSTRATING THE BEHAVIOR OF A COLUMN OR STRUT ACCORDING TO EULER'S THEORY

The methods of determining the strength of individual struts, as described, can be applied only to slender or Euler-class struts, that is, struts whose slenderness ratio is higher than a certain limit, depending on species of wood and end fitting or condition of strut. For spruce and fir struts on pin or knife-edge supports this limit is about 100. Probably all interplane struts, except some stocky ones for seaplanes, fall in the Euler class. Hence the methods have wide application.

The first method is direct. It consists in actually subjecting the strut to an ordinary test for maximum load; that is, the strut is loaded gradually in a non-follow-up load testing machine until the maximum load is reached and ascertained. As theory indicates and many actual tests have proved, this test does not injure the slender strut. In the field of testing slender struts are unique, for no other structural member can be tested directly to ultimate strength without injuring it.

The second method is indirect. It consists in making a simple bending-test of the strut for certain data; then these data are used to calculate the ultimate strength of the strut. The entire method is simple and, though indirect, gives good results for slender struts.

THE DIRECT METHOD

Briefly, the Euler theory of columns is that if a slender, straight, elastic and homogeneous column be subjected to increasing axial load, it will not deflect but when a certain critical value of load is reached the column is in an unstable state and any slight deflecting force would cause a considerable deflection. The column would then remain in the deflected position under the critical load and any slight increase of that load would cause increasing deflection and finally failure. Thus the critical or Euler load is also the maximum or crippling load.

The line *oabc*, Fig. 1, represents this Eulerian strut behavior in an ordinary test, wherein the loading or moving head of the testing-machine is gradually and steadily

[1] Consulting engineer, Forest Products Laboratory, Madison, Wis.

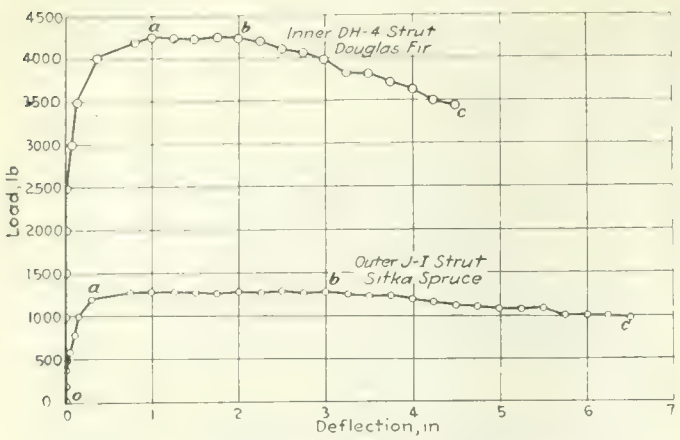


FIG. 2.—LOAD-DEFLECTION CURVES OF TWO STRUTS

screwed down until failure of the strut occurs. The ordinates are the loads and the abscissas are the center deflections; thus the line *oabc* is a load-deflection graph. In the first stage, *oa*, the strut takes on a load without deflecting; in the second, *ab*, it deflects without any increase of load; in the third stage it deflects under diminishing load. The line *bc* may not be straight actually, but this is immaterial. The elastic-limit stage of the test is denoted by *b*.

According to the Euler theory, therefore, a slender, elastic, straight and homogeneous column can be loaded to its ultimate strength without injury, assuming that straining the material within its elastic limit does not injure it. The stress in the column at the stage *a* is wholly direct; at *b* mainly bending. In very slender struts the difference between these stresses is large and so the margin of safety, based on stress, of the column in the stage *a* is large.

Airplane struts are not perfectly straight and homogeneous, and their loads are not applied precisely axially. Moreover, the Euler theory is known to be imperfect. Hence, one would not expect a strut under test to behave exactly in accordance with the Euler theory. In spite of minor imperfections, however, the load-deflection graphs for slender interplane struts are decidedly Eulerian. Two such cases are described and discussed in the following paragraphs.

The lower curve in Fig. 2 is the load-deflection graph from an outer J-1 strut, whose slenderness ratio was 215. The departure of *oa* from the vertical is due to the non-axial application of the load and a lack of straightness and uniformity of the strut. But this departure is immaterial in the present connection. The important feature is *ab*, which indicates that this strut took on its maximum load much before deflecting to the elastic limit stage *b*. This load-deflection graph clearly shows that the strut behaved closely in accordance with the Euler theory, and presumably was not injured in loading up to maximum load. The greatest stress, combined compression and flexure, in this strut at the stage *a* was about 35 per cent of the greatest stress at the stage *b*.

The upper curve in Fig. 2 is the load-deflection graph for an inner DH-4 strut whose L/r was 165. In this case, too, the behavior of the strut in the test was closely Eulerian. At the stage *a* the greatest stress in the strut was about 55 per cent of the greatest stress at the stage *b*. Here, again, there was a safe test margin between the two stages.

Many other load-deflection graphs were obtained which agree more or less closely with the Euler or "theoretical" graphs. They afford good reason for believing that loading a slender interplane strut to its maximum load does not injure it. But even better reasons for the belief are given in the next paragraphs.

About 20 struts were tested repeatedly to their maximum load for the express purpose of ascertaining whether such loading injures a strut. One of the first of these, a spruce J-1 inner strut, was loaded 19 times. The first 17 runs were not carried to the elastic-limit stage and the strut was evidently not being injured. In the eighteenth run the loading was carried beyond the elastic-limit stage, 2¾-in. deflection, and in the nineteenth that strut failed, as was expected, to stand up to previous maximum loads. Eight other J-1 struts with an L/r ratio of from 185 to 225 were loaded repeatedly to their maximum load without any apparent injury.

For further confirmation, six inner DH-4 struts having an L/r value of about 165 were loaded repeatedly under more favorable testing conditions. The load-deflection graphs for tests of two of these struts are shown in Figs. 3 and 4. It will be noted that the maximum loads in the successive runs, three in the case of the Douglas-fir strut of Fig. 3 and six for the Sitka-spruce strut in Fig. 4, were practically equal. Tests of the other four struts gave the same maximum load in the successive runs.

Routine tests have been made on about 750 interplane struts, mainly of Sitka spruce and Douglas fir for J-1 and DH-4 airplanes. A few tests were made on bakelized, canvas-covered Sitka spruce, taped Sitka-spruce and

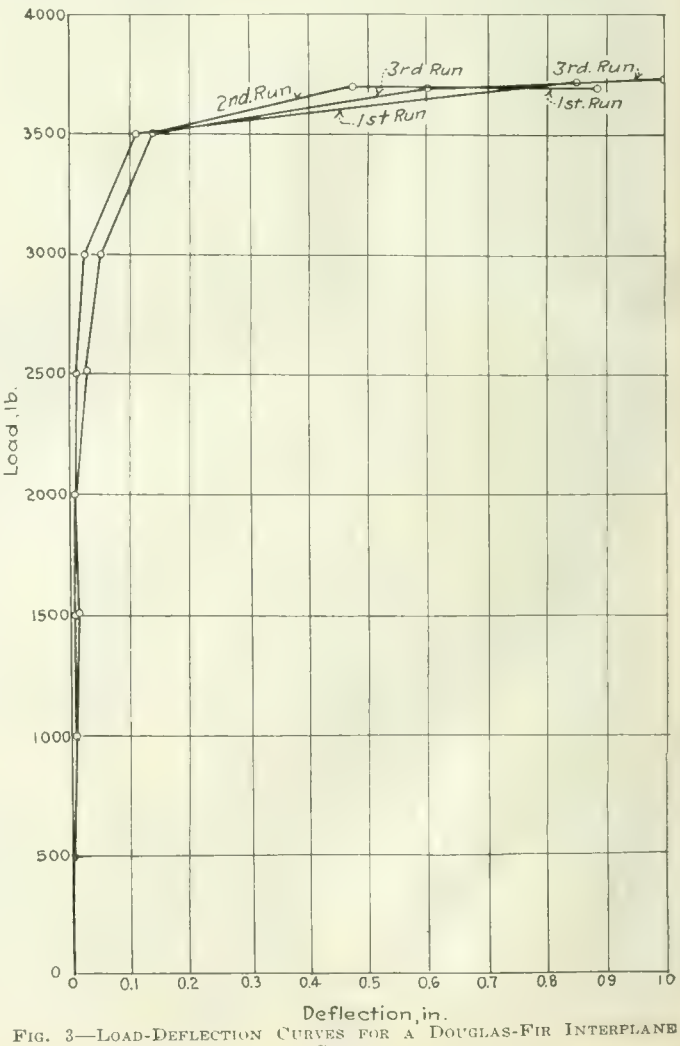


FIG. 3—LOAD-DEFLECTION CURVES FOR A DOUGLAS-FIR INTERPLANE STRUT

Douglas-fir struts, and built-up struts with yellow-birch veneer-covering and Sitka-spruce reinforcement. Most of these struts were subjected to their maximum load two or more times. Successive applications of load invariably gave about the same maximum load as the first. The relatively small differences are ascribable to slipping of the fittings or supports or to errors involved in rapid testing. When knife-edge supports were used, the agreement was always very good.

In making this test care should be taken to stop it promptly after reaching the maximum load, to reduce

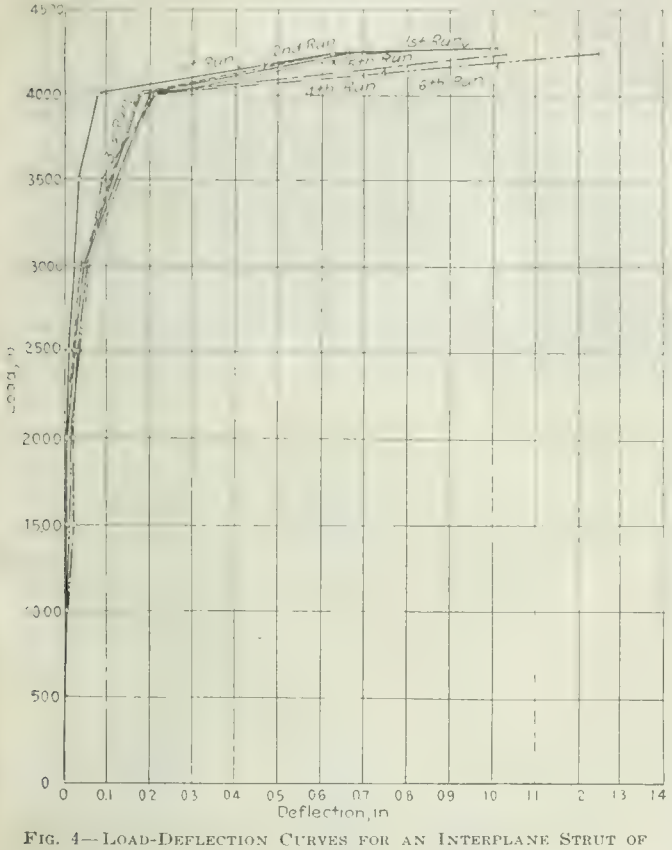


FIG. 4—LOAD-DEFLECTION CURVES FOR AN INTERPLANE STRUT OF SITKA SPRUCE

the likelihood of injuring the strut. With very slender struts this caution is not important because the elastic-limit stage comes long after the maximum load is first reached, as already explained. An experienced operator with a suitable sensitive testing-machine can easily catch the maximum-load stage promptly by paying careful attention to the weighing beam. From the beginning of the test he keeps the beam balanced by running out the poise. When the maximum load is approached the rate of poise movement required becomes less and less, and at maximum load the poise is stationary.

Testing for the maximum load is best done with two operators, one to handle the poise and call out the loads at regular intervals and the other to read and record the deflections at the announced loads. The recording is done graphically, so that a load-deflection graph is constructed as the test progresses. This graph gives the best value of the maximum load and affords a ready comparison with the second run, which is invariably made as a check and for other information.

Strut tests should be made with knife-edge supports, since these afford better results. Supports like those used in J-1 and DH-4 airplanes involve more or less friction as the strut bends in the test, and often incur appar-

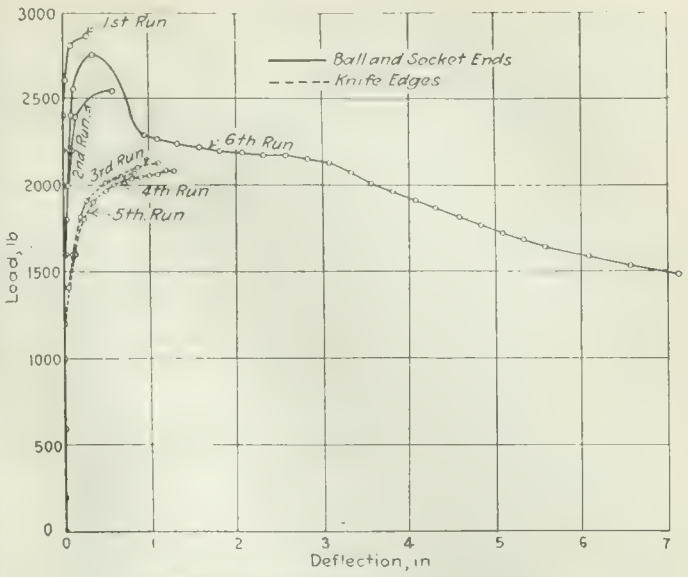


FIG. 5—LOAD-DEFLECTION CURVES OF A STRUT TESTED ON ITS OWN BALL-AND-SOCKET FITTINGS AND ALSO ON KNIFE-EDGE SUPPORTS

ent anomalies that may mislead an inexperienced operator. The graphs in Fig. 5 in the case of which runs 1, 2 and 6 were made with the strut on its own ball-and-socket fittings and runs 3, 4 and 5 with the strut on knife-edge supports, will illustrate this point. The "humps" in the graphs of runs 1, 2 and 6 are due to friction in the ball-and-socket fittings. For reasons stated in a later paragraph, curves 3, 4 and 5 are regarded as the proper indications of the strength of the strut as used in the airplanes. Fig. 6 shows load-deflection graphs of a strut tested on regular DH-4 supports. The hump h is due to a peculiarity of the fitting.

THE INDIRECT METHOD

Euler's column formula seems to be in most common use for calculating the strength of interplane struts, and the method under discussion is based mainly on that formula, which may be written

$$Q = C\pi^2 EI/L^2 \qquad (1)$$

where

C = a coefficient depending on the "end conditions" of the strut as such
E = modulus of elasticity of material
I = moment of inertia of section of support of the strut as a beam
L = the effective length of the strut or the distance between pins, balls or whatever the supporting points are
Q = total load on column

Imagine a strut supported flatwise near its ends and then subjected to a moderate cross-bending load so that the strut as a beam is not overstrained. The deflection caused by the load is given by

$$d = K(Pl^3/EI) \qquad (2)$$

where

d = deflection caused by the load P
K = a coefficient depending on the loading and manner
l = span in the beam test
P = any moderate load not overstraining the beam

For any given strut equations (1) and (2) can be combined. Combining to eliminate E and I gives the desired formula for the maximum or crippling load of the strut, namely

$$Q = CK\pi^2(l^3/L^2)(P/d) \qquad (3)$$

For struts on knife-edge supports $C = 1$. Struts on ball-and-socket and pin supports and the like in flying

airplanes are subjected to vibration which breaks down the friction at the supports and makes the supports equivalent to knife-edges. Hence it seems wise, as in practice, to calculate the ultimate strength of airplane struts on the basis of knife-edge support; that is, with $C = 1$.

Center and third-point loading were considered the most suitable methods in testing the strut as a beam; other methods were regarded as impractical. By actual trial of 12 struts it was found, contrary to expectation, that center loading gave the better results; accordingly, that loading was finally decided upon. For such loading and simple non-restraining supports, $K = 1/48$. Hence equation (3) becomes

$$Q = 0.206\,(I/L^2)\,(P\ d) \qquad (4)$$

which is the final form. It will be noted that P and d or their ratio are the only quantities for which a test must be made to furnish the value of Q for any particular strut. This ratio is the center load per inch of deflection and is therefore a measure of the stiffness of the strut. Hence, the test is for the stiffness of the strut, which is needed in calculating the bending strength.

For struts not uniform in cross-section or composition the Euler column and the beam deflection formulas still hold; of course, appropriate mean or average values of E and I must be used in each. But are these average values in the column formula respectively equal to those in the deflection formula, permitting their cancellation or elimination? This question cannot be answered positively for all non-uniform struts, but tests of 20 tapered solid struts (10 outer and 10 inner struts for the J-1 airplane) and 5 built-up struts of the five-piece, veneer-covered type indicate that such cancellation is substantially correct. That is to say, the second method of tests, based on formula (4), was applied to these struts and gave very good results.

Verification of Method by Actual Trials

Fifty-five struts were tested by this method and, for comparison, by the first method also. To insure good results the tests by the first method were made with struts on knife-edge supports; the results are recorded in the third column of Table 1. The results by the second method are recorded in the fourth column. The percentage of difference between the two methods appears in the last column. The differences are decidedly small, and the test verification of the theory of this second method is highly satisfactory. The table includes solid and built-up fir and spruce, and uniform cross-section and tapered struts.

It will be noticed that some of the struts were tested on two spans, one of which was practically the maximum

TABLE I—CRIPPLING LOADS FOR VARIOUS TYPES OF INTERPLANE STRUT

Strut Number	Kind and Species	Load as Measured in Column Test, Lb.	Load as Calculated from Beam Test, Lb. Span, In.		Difference Between the Two Results, Per Cent Span, In.	
			52	60	52	60
Solid Struts of Uniform Section						
DH-4	Inners					
G-41	Spruce	5,175	5,380	5,390	−4 0	−4.1
G-42	Spruce	6,350	6,420	6,530	−1 1	−2.8
G-56	Spruce	5,125	5,270	5,530	−2.8	−7.9
G-57	Spruce	4,375	4,310	4,575	+1.5	−4.6
G-64	Spruce	3,445	3,640	3,645	−5 6	−5.8
DH-4	Outers					
G-70	Fir	2,075	2,040	2,080	+1.7	−0.2
G-74	Fir	2,240	2,200	2,180	+1.8	+2.7
G-76	Fir	2,560	2,520	2,570	+1.6	−0.4
G-79	Fir	2,020	2,035	2,060	−0 7	−2.0
G-80	Fir	2,460	2,485	2,510	−1 0	−2 0
J-1	Inners					
D-1	Spruce	2,540	2,570	2,51)	−1.2	+1.2
D-13	Spruce	1,800	1,750	1,820	+2.8	−1.1
D-14	Spruce	1,975	1,920	1,945	+2.8	+1.5
D-17	Spruce	1,950	1,920	2,030	+1.5	−4.1
D-2	Fir	2,17)	2,220	2,200	−2.3	−1 4
J-1	Outers					
D-19	Spruce	1,450	1,425	1,430	+1.7	+1.4
D-20	Spruce	1,235	1,195	1,200	+3.2	+2.8
D-21	Spruce	1,060	1,010	1,030	+4 7	+2.8
D-7	Spruce	1,415	1,355	1,385	+4.2	+2.1
D-8	Spruce	1,390	1,385	1,360	+0.4	+2.2
Average					2.4	2.7
Solid Tapered Struts				64		64
J-1	Inners					
D-1	Spruce	2,275		2,450		−7.1
D-13	Spruce	1,700		1,720		−1.2
D-14	Spruce	1,790		1,835		−2.5
D-17	Spruce	1,775		1,750		+1.4
D-19	Spruce	1,400		1,430		−2.1
D-2	Fir	2,030		2,120		−4 4
J-1	Outers					
D-20	Spruce	1,165		1,210		−3.9
D-21	Spruce	1,000		1,040		−4.0
D-7	Fir	1,300		1,330		−2.3
D-8	Fir	1,315		1,350		−2.6
Average						3 2
Hollow Built-Up Struts of Uniform Section[2]				60		60
J-14	All spruce and birch	4,250		4,160		+2.1
J-15						
J-16		4,815		4,710		+2.2
J-17		3,760		3,600		+4.2
J-18		3,500		3,540		−1.1
J-19		3,425		3,440		−0.4
Average						2 0

Strut Number	Kind and Species	Load as Measured in Column Test, Lb.	Load as Calculated from Beam Test, Lb. Span, In.	Difference Between the Two Results, Per Cent Span, In.
Hollow Built-Up Struts			96	96
N-1		4,840	4,920[3]	+1.5
			4,890	+0.9
2		5,170[3]	5,380	...
			5,550	.....
		3,700[3]	4,030	....
			3,940	. .
4		4,930	4,900	−0.6
			5,000	+1.4
5		5,350	5,510	+3.0
			5,500	+3.0
6		5,300	5,550	+4.7
			5,560	+4.9
7		4,960	4,920	−0.8
			5,160	+4.0
8		5,100	4,860	−4.7
			5,070	−0.6
9		5,800	5,990	+3.3
			5,700	−1 7
10		4,970	4,890	−1.6
			4,800	−3.4
Average				2 5
O-1		14,200	15,000	+5.6
			15,000	+5.6
O-2		12,050[3]	13,120	.....
			13,250	. .
O-3		13,240	13,250	0 0
			13,250	0.0
O-4		12,060	12,500	+3.6
			12,860	+6.6
O-5		12,830[3]	13,680	.....
			13,300	...
O-6		13,100	13,820	+5.5
			14,080	+7.5
O-7		12,250	13,120	+7.1
			13,120	+7.1
O-8		11,350	12,330	+8.6
			12,250	+7.9
O-9		12,500	13,750	+10.0
			13,000	+4.0
O-10		13,520[3]	14,100	. . .
			14,100	....
Average				5.6

[2]The core was a double box made of spruce covered or streamlined with two plies of spruce, the inner was longitudinal and about ⅛ in. thick, the outer circumferential and about 1/32 in. thick.

[3]Not maximum load or ultimate strength.

[4]In this group of struts the calculations were made for the strut in a normal horizontal and a reversed horizontal position.

that the strut afforded. The two were tried out to ascertain whether choice of span is important. As was expected, the choice was unimportant with struts of uniform cross-section, but with tapered struts the longer span gave the better results. Several struts were tested twice on the same span. In the second test the strut was turned over so that the side which was the upper in the first test was the lower side in the second. The values of P/d and hence of Q, in the two tests were practically alike in each case. As previously stated both center and third-point loadings were tried on about 12 struts and center loading gave better results.

A high degree of skill is not necessary, although for good results care should be taken about details. Both ends of the strut should be supported freely, so that bending is not hindered by them. The supports should be such that there is no doubt where the points of support are, because the exact value of span is required for use in formula (4). The bending load, P, is small compared with the maximum load for the strut as such; weighing apparatus correct to 1 or 2 lb. should be provided for measuring P. At the laboratory the bending load was applied with a 50,000-lb. testing-machine. One end of the strut, however, was supported on a small platform scale reading to quarter-pounds, which furnished accurate values of P. The deflection should be read with reference to points not on the machine but on the strut immediately over the support. For best results a single value of P/d should not be relied upon. The laboratory practice is to read both loads and deflections for a load-deflection graph; the mean straight line gives the best value of P/d for use in the formula. Of course, the loadings should not be carried to the elastic-limit stage. In the tests of J-1 and DH-4 struts deflections were run up to ½ in., really more than was necessary; all that is necessary is enough of the straight load-deflection graph to determine its slope, or P/d.

Meaning of Slender or Euler Class Strut

In the preceding discussion it is stated repeatedly that the two methods as explained hold only for slender or Euler-class struts. The question as to how slender a strut must be to put it into the Euler class will not be considered. Like most of the theory of elasticity, the theory of Euler's formula predicates stress within the elastic limit, and so the formula applies strictly only within that limit. That is $Q/A = C\pi^2 E \div (L/r)^2$ must not be greater than the elastic limit for the strut in question. Thus the formula for a particular strut holds only if the value of Q/A is equal to or less than the elastic limit of the material in compression. Again, if S denoted elastic limit, L/r must not be less than CE/S; hence $L/r = \pi\sqrt{(EC/S)}$ is the calculated lower limit of the slenderness ratio for Euler-class struts.

For Sitka-spruce struts with pin ends where $C = 1$, this formula gives a limit between 50 and 60 which is much lower than the limit shown by tests. Thus, in a paper[5] by Com. J. C. Hunsaker, U. S. N., reporting some tests, the limit is given as 70 for spruce with pinned fastenings; and the Navy Department[6] apparently sets the limit at 100 for spruce struts with pin ends.

The wide difference between the calculated and the observed limits is probably due, in part, to eccentric loading in the test of struts near the limit, or to imperfections in the strut that would have the same effect, and to lack of linear distribution of the stress on the cross-sections of the strut. It may be noted that the same difference is known to exist in the case of metal struts. For example, see Fig. 7 which shows the graph of Euler's formula, for wrought-iron struts with round ends, the ordinates and abscissas being values of Q/A and L/r respectively. The yield-point stress for the material is 36,000 lb. per sq. in. Hence one might expect the Euler limit L/r to be about 85. Actually the strengths of the shorter struts are represented closely by the curve ac; that is, the Euler limit L/r is about 120 for such struts.

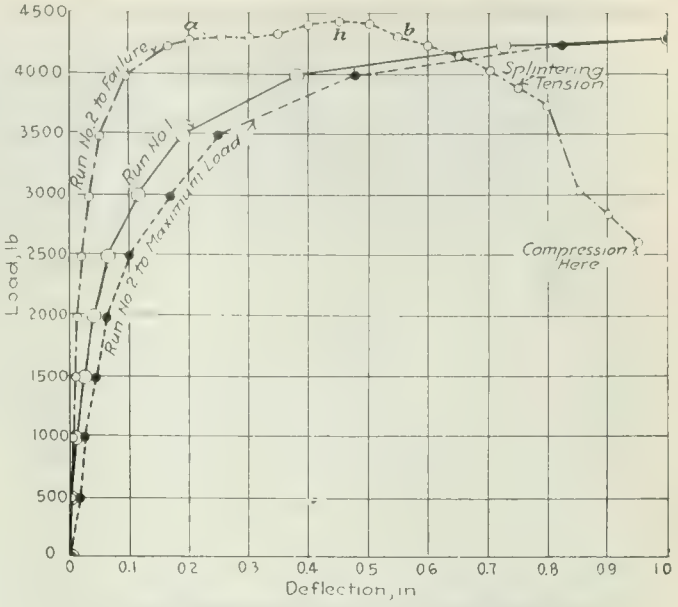


Fig. 6—Load-Deflection Curves of a Strut Tested on the Regular Supports Used in a DH-4 Airplane

For additional information on the limiting value of L/r for the quality of Sitka-spruce and Douglas-fir used in airplane struts, as represented by solid DH-4 struts sent to the laboratory from time to time, three Sitka-spruce and three Douglas-fir DH-4 struts were subjected to the following special tests: Each strut, which originally had an L/r ratio of about 165, was shortened successively to $L/r = 140$, 120, 100, 90 and 80; and the strengths of these struts of various lengths were determined by our two methods. Table 2 gives the more im-

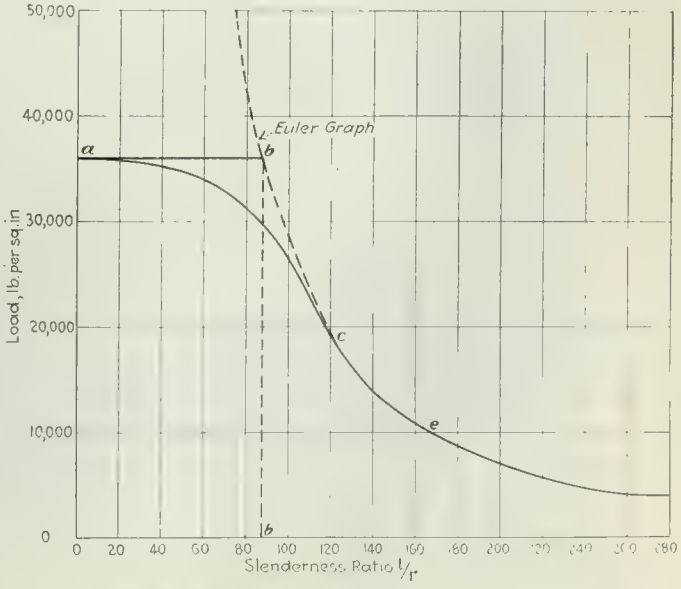


Fig. 7—Curve Giving Strength Values for Wrought-Iron Struts with Round Ends Plotted According to Euler's Formula

[5] See *Aerial Age Weekly*, Aug. 16, 1915, p. 524.

[6] See General Specifications for Airplanes issued by the Navy Department in January, 1918.

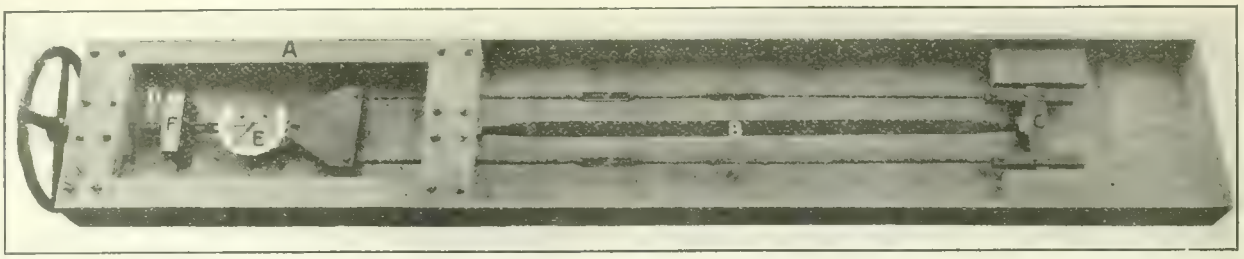


FIG. 9—ANOTHER AND MORE RECENT STRUT-TESTING MACHINE, ALSO OF THE DIRECT TYPE DESIGNED FOR STRUT LOADS UNDER 5000 LB.

portant test data and calculated results. The last column gives the differences between the two determined ultimate strengths. It will be noticed that for strut G-96, the maximum loads as measured in the column test and calculated from the beam test agree fairly well for the

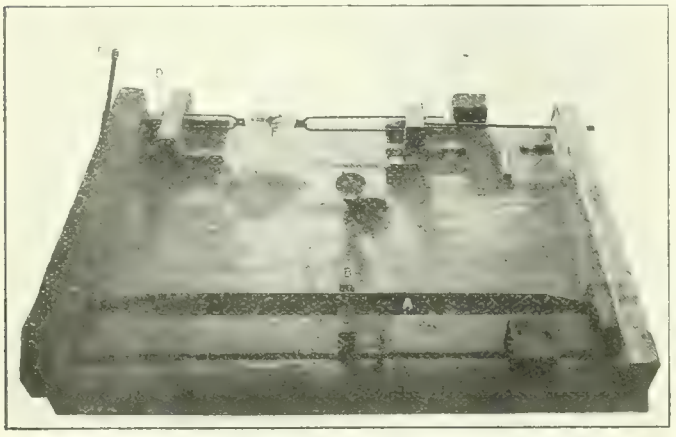


FIG. 8—STRUT-TESTING MACHINE OF THE DIRECT TYPE THAT EMPLOYS THE LEVER PRINCIPLE

successive values of L/r down to and including $L/r = 100$, but that for $L/r = 80$ the column-test load differs much from the beam-test load. Since the latter is calculated by Euler's formula, it appears that the limit value of L/r for G-96 was between 100 and 80. For G-98 the limit was between 90 and 100; for G-102, between 100 and 120; and for the three fir struts, between 80 and 90.

TABLE 2—CRIPPLING LOADS FOR STRUTS OF VARIOUS SLENDERNESS RATIOS

Strut Number	Effective Length of Strut, In.	Slenderness Ratio	Load as Measured in Column Test, Lb.	Span in Beam Test, In.	Ratio of Load to Deflection, Lb. Per In.	Load Calculated from Beam Test, Lb.	Difference in Results, Per Cent
			Spruce Struts				
G-96	65.9	166.0	4,740	64.0	400	4,960	—4.6
a	55.6	140.0	6,950	53.6	694	7,120	—2.4
b	47.6	120.0	8,895	45.6	1,104	9,520	—7.0
c	39.7	100.0	12,450	37.7	1,850	13,000	—4.4
e	31.7	80.0	18,300	29.7	4,120	22,200	—21.3
G-98	65.9	165.4	4,450	63.9	379	4,690	—5.4
a	55.6	140.0	6,625	53.6	654	6,750	—1.6
b	47.7	120.0	9,000	45.7	1,082	9,440	—4.9
c	39.8	100.0	13,200	37.8	1,850	13,100	+0.8
d	35.8	90.0	15,800	33.8	2,750	17,100	—8.2
e	31.8	80.0	17,325	29.8	3,700	20,000	—15.4
G-102	65.9	165.4	4,600	63.9	380	4,700	—2.2
a	55.6	140.0	6,250	53.6	650	6,660	—6.6
b	47.7	120.0	9,000	45.7	1,080	9,220	—2.4
c	39.8	100.0	11,750	37.8	1,860	13,200	—11.9
d	35.8	90.0	13,200	33.8	2,500	15,500	—17.5
			Fir Struts				
G-97	65.9	165.5	6,550	63.9	550	6,800	—3.8
a	55.6	140.0	9,450	53.6	957	9,840	—4.1
b	47.7	120.0	12,650	45.7	1,508	13,100	—4.3
c	39.8	100.0	18,075	37.8	2,675	19,000	—5.1
d	35.8	90.0	21,750	33.8	3,470	21,500	+1.1
e	31.8	80.0	27,300	29.8	5,700	30,800	—12.8
G-99	65.9	166.5	5,375	63.9	442	5,430	—1.0
a	55.5	140.0	7,700	53.5	774	7,920	—2.8
b	47.5	120.0	10,750	45.5	1,222	10,400	+3.3
c	39.6	100.0	14,575	37.6	2,220	15,560	—6.7
d	35.6	90.0	17,950	33.6	2,965	18,250	—1.7
e	31.6	80.0	21,700	29.6	4,090	25,900	—19.3
G-103	65.2	169.0	5,850	64.2	476	5,940	—1.5
a	54.7	140.0	9,275	52.7	892	9,000	+3.0
b	46.9	120.0	11,450	44.9	1,457	12,300	—7.4
c	39.1	100.0	17,350	37.1	2,500	16,800	+3.2
d	35.2	90.0	22,350	33.2	3,540	21,600	+3.3
e	31.2	80.0	28,000	29.2	4,550	24,000	+14.3

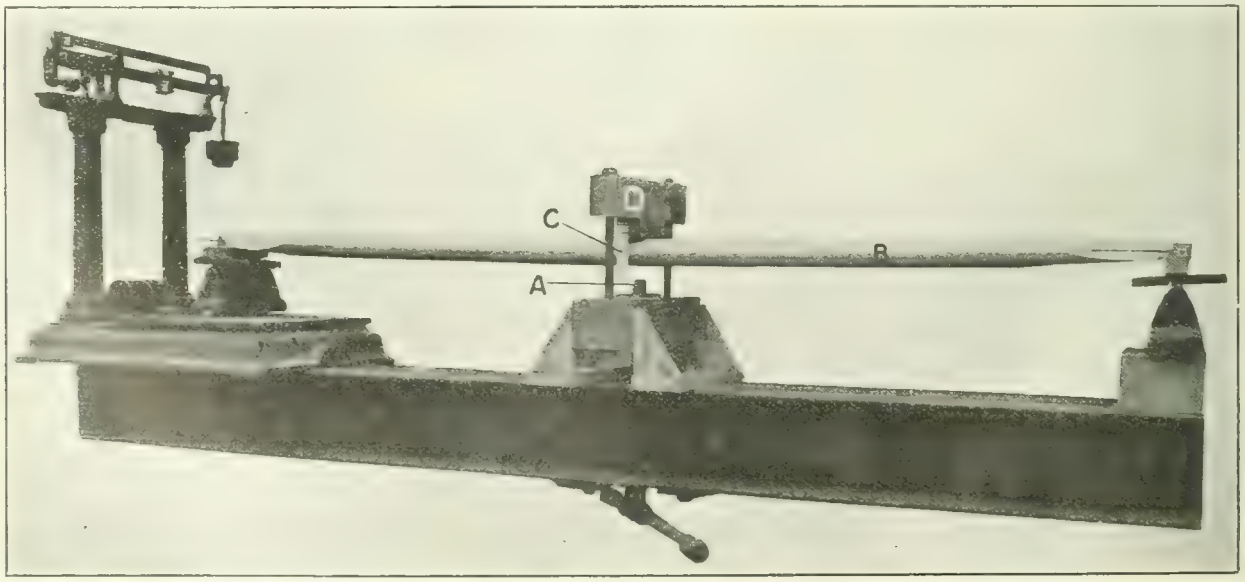


FIG. 10—A STRUT-TESTING MACHINE OF THE BEAM TYPE WHICH ALSO WAS DEVELOPED BY THE FOREST PRODUCTS LABORATORY

The conclusion, therefore, is that for such Sitka-spruce or Douglas-fir struts supported on knife-edges or the like, the Euler limits are about 100 and 90 respectively.

Some Homemade Strut-Testing Machines

The methods for determining the strengths of struts already described are not only simple but the tests required in either method can be made with a very simple machine. Three such machines have been built at the laboratory and tried out with satisfactory results.

The first machine for testing strength by the direct method, which is shown in Fig. 8, employs the lever principle and is especially suitable for large strut loads of over 5000 lb. The strut *A* which is to be tested is supported by two knife-edge fulcrums, one at each end, excessive deflection through careless operation being limited by the stops *B* and *C*. The pulling rig consists of an ordinary carpenter's bench-vise screw *D* which has eight threads to the inch. Turning the handle *E* causes a pull to be registered on the spring dynamometer *F* and this pull is transmitted by a multiplying lever to the strut as a strut load. The dial *G* is not used in making strength tests but is employed for measuring the deflection of the strut.

The second machine, Fig. 9, is of the direct-pull type without any multiplying lever and is especially suitable for strut loads under 5000 lb. It consists of a long shallow box, into one end of which a rigid and strong frame *A* is built. The strut *B* is placed for testing between one end of the frame *A* and the headpiece *C*. The load is applied to the strut by the handwheel on the screw *D*, through the spring dynamometer *E* and pulling rods to the headpiece *C*. These rods extend freely through the strut-supporting member of the frame *A* and are supported at their outer ends by the headpiece *C*. A wooden block *F* surrounds the pulling nut and prevents it from turning as well as affording an attachment for the dynamometer. Means of adjustment for different strut lengths are afforded by four turnbuckles, two in each pulling rod, and the two distance-rods connecting each pair of turnbuckles.

In the beam machine illustrated in Fig. 10 the base of the entire appliance is formed of I-beams that support the weighing scale, the loading screw *A* and one end of the strut *B*. The middle deflections of the strut are measured by the usual device consisting of a thread stretched between two points on the strut just over the supports and a suitable vertical scale *C* directly behind this thread and fixed to the strut or to the loading block *D*.

TRACTIVE RESISTANCE OF ROADS

IN connection with research on tractive resistance of roads, contemplated in the highway research program of the Committee on Economic Theory of Highway Improvement, Engineering Division, National Research Council, Major Mark L. Ireland has been assigned by the Quartermaster General of the Army to work at the Massachusetts Institute of Technology, which will be confined for the present to determining the tractive resistance of concrete-surfaced highways to 1½ and 3-ton internal-combustion-engined motor trucks. It is proposed to vary the speed, load, tire equipment, grade and curvature of highway before taking up research on other types of road surface. Major Ireland, whose address is Electrical Engineering Department, Massachusetts Institute of Technology, Cambridge 39, Mass., has requested that members of the Society furnish experimental data that they consider pertinent and valuable in the connection, on tractive resistance of roads, the manner of energy absorption in motor vehicles, gasoline consumption of various vehicles on various roads, scientific testing of automobiles, and economics of highway transportation.

STORE-DOOR DELIVERY

A GENERAL outline covering store-door delivery in our large shipping and receiving centers is as follows: The carriers when unloading freight in their terminals would be required to segregate freight on their piers for delivery to such zones as might be agreed upon among the shippers, teaming companies and carriers. The teaming companies acting either as agents for the shippers or carriers, would then load all freight for delivery within a particular shipping zone and delivery would be made direct to the consignee's door or warehouse without delay. By the elimination of delays to trucks and by full loading, the cartage charges would be materially reduced, which should prove mutually advantageous to all parties concerned.

Similar arrangements could be made to take care of outbound shipments, which could be delivered to the teaming companies under a similar arrangement, covering inbound shipments, delivery to be made as far as possible in the afternoon.—W. J. L. Banham in *The Commercial Vehicle.*

MOTORSHIPS

IT is of considerable interest to note that the motor-car industry, in which America now leads the world, developed in Europe in much the same way as the motorship industry, and it is not too much to expect that once American interests become convinced that the motorship is what the Europeans think it is, American motorship construction and operation will also lead the world.—Charles E. Lucke in *Mechanical Engineering.*

INCH SIZE ROLLER BEARINGS

IN Table 8 which appeared on page 70 of the July issue of The Journal giving the dimensions of various roller bearings for motor-truck hubs an unfortunate typographical error occurs in connection with the Bock inner bearing for spindle No. R 9. The numbers in parenthesis should have been 6379-6310 instead of 63-6310.

ACTIVITIES OF THE SECTIONS

IF the coming meetings of the Metropolitan Section are as successful as was the outing on Saturday, July 30, the Section has a busy year ahead. Apparently no financial depression had affected the New York crowd and business was evidently good enough to justify everyone taking a day off. About 150 members and guests boarded the steamer Squantum for the cruise, which comprised a run up Long Island Sound and bathing, stunts and dinner at the Chateau Laurier, City Island, New York.

The outing, not to be outdone by the Summer Meeting of the Society at West Baden and French Lick, had its technical side, most of the technique being shown by the playing of the members of the colored jazz orchestra when they were not playing, if you get what we mean; by President Beecroft's agility as an umpire; by Al Bergmann's dexterity as a dancer and the Squantum's ability to keep an even keel at the same time; by the aquaplaning by Vic Kliesrath behind his motor-boat Krazy Kat; and finally by the planning and running of the whole affair by the Chairman of the Outing Committee, Ethelbert Favary, who was disguised as an officer of the Swiss Navy.

Eleven new members of the Section were secured during the trip and their initiation proved inspiring to the Membership Committee which had been working a long time over some of them.

Aberdeen Proving Ground

The Washington, Pennsylvania and Metropolitan Sections will join with the parent Society in accepting the invitation extended by General Williams, chief of Ordnance, to visit the Aberdeen Proving Ground on Oct. 7.

The program will consist in part of

(1) Firing of small arms, including tracer bullets from machine guns
(2) Firing of mobile guns
(3) Firing of major caliber guns from 12-inch to 16-inch
(4) Demonstration of tanks, tractors and trailers
(5) Demonstration of bomb-dropping from balloons and airplanes

According to War Department regulations, admission will be limited to citizens of the United States with the exception of those manufacturing munitions for a foreign government which is at war.

Coming Professional Sessions

A preliminary announcement can now be made of the plans of a number of the Sections for the coming months.

The Dayton Section expects to hold its first fall meeting about Oct. 1. The subject will be radiation and will probably be treated by one of the officers of McCook Field. About Dec. 1 a paper on lubrication will be given, and in February one on all-metal airplane design.

The Indiana Section will have a paper on Chassis Design at its opening meeting of the season which is scheduled for Sept. 23.

The Metropolitan Section on Sept. 15 will give a synopsis of the papers presented at the Fuel Session of the Society held in May. Other subjects to be taken up are the factors affecting the design of rear axles for trucks, in November; the commercial development of the airplane, in December; and during the remainder of the year, chassis lubrication, power absorption from the flywheel to the road, car performance and how to obtain a definite factor representing it, and traffic problems including that of parking space.

Tentative dates for Detroit Section meetings are Sept. 23, Oct. 21, Nov. 18, Dec. 23, Feb. 24, March 24, April 28 and May 26. Subjects to be considered include

(1) Fuel Problem
  (a) A discussion of the different types of carbureters in use
  (b) Quality and distribution of gas
  (c) Piston design
  (d) Cylinder-wall surfaces from a production standpoint, including a discussion of the advantages of grinding versus draw-lapping
  (e) Lubrication systems, particularly as to proper cylinder-wall lubrication and a study of the methods for reducing the dilution of the oil-film by unburned fuel
(2) Research—A continuation of the work on this subject that was started last season
(3) Progress of Aeronautics—Commercial aviation and advances made
(4) Passenger-Car Bodies—Work of draftsmen and designers
(5) Production—The possibilities of a decreased cost of motor-car building

Although the dates have not been announced, the Mid-West Section plans to hold a series of meetings given over to the discussion of thermodynamics, principles of carburetion, combustion phenomena and the fundamental losses in internal combustion engines.

The Minneapolis Section will have sessions during the season on manifold design and fuels, tractor wheels and traction, steam power for farm tractors, road-building machinery and engineering, power cultivators and tools, engine-to-ground power absorption in tractors, and tractor publicity and demonstrations. The engineering sessions will in most cases be preceded by informal talks on non-technical topics by prominent executives.

The Pennsylvania Section will open its season with a meeting at the Torresdale Golf Club on the afternoon and evening of Thursday, Sept. 22. Sports will occupy the afternoon. After dinner there will be a brief discussion of some of the more important papers that were presented at the meeting of the Society held in May. President Beecroft has accepted an invitation to be present. In November there will be a Diesel engine and fuel meeting, in December an aviation session and in January a discussion of the Society 1922 Annual Meeting papers with the authors of several of these papers in attendance. The February session will be devoted to consideration of current business conditions, that of March to electrical equipment, and in April commercial motor transportation, truck axles and springs will be discussed. The Section year will close in May with an inspection trip to one of the nearby body-building plants and an evening session on body engineering.

GEOLOGICAL TIME

ONE of the most fundamental conceptions of geology is the vast duration of geological time. We are accustomed to count time in days, months and years, but in geology time is counted in millions of years. Estimates of the age of the earth, based on several lines of reasoning, vary from 20,000,000 to more than 1,000,000,000 years. The figure most widely accepted is 90,000,000 to 100,000,000 years. If we consider the relation of the life of an individual who attains the age of 70 to the possible age of the earth, we may, perhaps, obtain a better understanding of the time involved. Dividing 100,000,000 by 70, we obtain the quotient, 1,428,571.43. The brief career of a person of this age would have about the same relation to the career of the earth as 1 sec. has to approximately 16½ days.—F. M. Van Tuyl in *Oil News*.

Current Standardization Work

THE July 1921 issue of data sheets for the S. A. E. HANDBOOK was sent to the members during August. These sheets contained the standards revised in accordance with the recommendations of the Standard Committee printed in the July issue of THE JOURNAL, pages 55 to 74 inclusive, and adopted by letter ballot of the voting members of the Society on July 23. The complete vote on the recommendations is tabulated below. The first column gives the number of affirmative votes; the second column, the negative votes; and the third, the number of members who did not vote either way.

Subject	Yes	No	Not Voting
Clutch Release Type Thrust Ball Bearings	182	5	151
Roller-Chain Sprockets	148	2	188
Roller Chains	149	1	188
Insulated Cable	112	2	224
Electrical Equipment Nomenclature	121	4	213
Magneto Couplings	144	1	193
Carbureter Flanges, Cast-Iron Type	189	0	149
Carbureter Flanges, Two-Bolt Type	194	1	143
Disc-Clutch Flywheel Housings	191	1	146
Rating of Storage Batteries (Cancellation)	112	4	222
Head-Lamp Brackets	157	1	180
Motorcycle Head-Lamp Mounting	116	0	222
Lamp Nomenclature	164	0	174
Bases, Sockets and Connectors	155	4	179
Exhaust Pipes	188	0	150
Square Shaft Fittings	182	0	156
Universal-Joint Hubs	181	2	155
Drain-Cocks	186	1	151
Stationary-Engine Belt Speeds	92	8	238
Stationary-Engine Rating	110	1	227
Lubricator Cups	103	0	235
Stationary-Engine Crankshafts	92	6	240
Hopper Capacities	93	1	244
Motor-Truck Bodies	129	1	208
Motor-Truck Hubs	138	3	197

Of the ballots mailed to voting members, 338 valid ballots were cast or 13.5 per cent.

The recommendation of the Stationary-Engine Division for stationary-engine belt speeds was not included in the July issue of the data sheets because, in view of the reasons submitted in support of the negative votes, it is desired to give further Division consideration to the recommendation before final publication.

AXLE AND WHEEL STANDARDIZATION

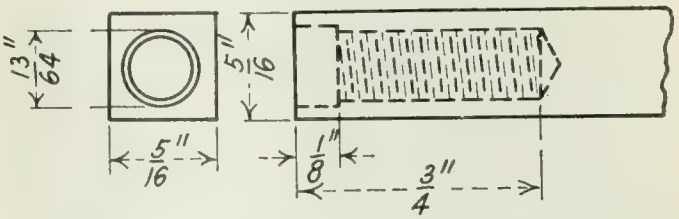
In order to make the work of the Axle and Wheel Division of most value to the axle and wheel manufacturers, a general letter has been sent out to them, requesting that they advise the Society of any additional parts that they feel the Division should undertake to standardize at the present time.

DOOR-FIT CLEARANCES

The Passenger-Car Body Division has tentatively recommended that the following door-fit clearances should be adopted as S. A. E. Standard for all types of body. The clearances are measured from wood-to-wood or metal-to-metal before painting.

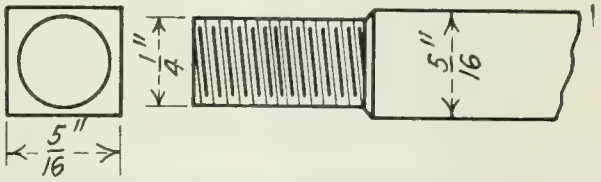
Location	Clearance, In.
Hinge Side	1/8
Lock Side	3/16
Bottom	7/32
Top	1/8
Jamb	3/16
Bead	3/32

The Passenger-Car Body Division has also tentatively recommended that door-handle squares shall be made from 5/16-in. cold-drawn key-stock as given in the accompanying illustrations.



Drill—No 21 (0.159 in.). Counter-drill—13/64 in. Thread—No. 10 (0.189 in.)—32 U. S. F. Usable length, 5/8 in. Pitch diameter limits, 0.1713 in. min., 0.1718 in. max.
INTERNALLY-THREADED TYPE

The counter-drill has been specified for the internally-threaded type to permit filing off the end of the shank to fit the job as variations, caused by machining the door-lock pillar, require variations in the end of the shank. Tolerances of plus or minus 0.001 in. have been specified for the material as it is felt that real workmanship requires these tolerances, which have been specified by certain automobile companies for several years.



Thread—¼ in.—28 S. A. E. Usable length, 3/8 in.
EXTERNALLY-THREADED TYPE

FLEXIBLE CONDUIT

A meeting of the Electrical Equipment Division Subdivision on Flexible Conduit was recently held at Cleveland. After considerable discussion regarding the use of flexible conduit on automotive vehicles, B. M. Leece, chairman of the Subdivision, appointed Clarence Renshaw a committee of one to obtain information on present and desirable practice for flexible conduit and to formulate a preliminary report covering dimensions and materials.

GENERATOR AND STARTING-MOTOR MOUNTINGS

A Subdivision of the Electrical Equipment Division has been appointed to review the present S. A. E. Standards and Recommended Practices for generator and starting-motor mountings, as several suggestions have been received in reference to extending and revising the present standards. The personnel of the Subdivision is T. L. Lee, chairman, R. G. Thompson and Ernest Wooler.

LAMP GLASSES

It has been suggested that the present S. A. E. Standard for head-lamp glasses or lenses be extended to specify the dimensions of lugs to prevent the glasses from turning in the head-lamps. This subject will be considered at the next meeting of the Lighting Division.

PASSENGER-CAR BODY NOMENCLATURE

George J. Mercer, Chairman of the Subdivision on Body Nomenclature, has submitted a report to the Passenger-Car Body Division. It is intended that by the time the names have been revised and adopted by the Division drawings will be ready to accompany each model described. The report follows:

Roadster—A small open-type body, with one fixed cross seat for two passengers and a space or compartment at the rear for carrying luggage. Emergency seats are sometimes made to fold into the luggage com-

partment or are located on the running-boards. Usually this body has two doors. The conventional type has a folding roadster top with emergency side-curtains that are removable.

Sometimes the roadster is made with a seating capacity for three or four on two fixed cross seats and is known as a four-passenger roadster. In this type the doors open directly to the front seats and access to the rear cross seat is obtained by an aisle that divides the front seats.

Touring—An open-type body with two fixed cross seats for four or five passengers. It may have folding emergency seats in the tonneau for two additional passengers. The body has four doors and a folding touring top with emergency side-curtains that are removable.

Touring-Phaeton—When a passenger-car builder markets two sizes of touring car body on the same size chassis, the smaller model is sometimes called a phaeton. Generally one is called a seven-passenger body and the other a five-passenger body.

Sometimes the touring model is made with the front seats separated by an aisle of sufficient width to permit a person to pass between them. This type is sometimes called the salon-touring body.

Sedan—An enclosed single-compartment body with two fixed cross seats for four or five passengers. Sometimes the front seats are divided by an aisle and the body has folding emergency-seats for two additional passengers. This type of body may have two, three or four doors. There are three movable glass windows on each side and the roof is fixed.

Berline—A body of the same description as the sedan, except that there is a partition at the rear of the driving seat that makes it an enclosed two-compartment body. One window glass in the partition is made so as to move vertically or horizontally.

Coupe—An enclosed single-compartment body with one fixed cross seat. This seat may be straight and seat two, or staggered and seat three. With the latter arrangement a collapsible seat may be placed by the side of the driving seat, thus making it a four-passenger body. There are two doors, two movable glass windows on each side and the roof is fixed.

Sometimes the seating plan is to have the two-passenger portion of the cross seat set back so that the passengers sit back of the driver's seat. The fourth seat is then usually a collapsible seat, but set back further.

Coupelet—A body of the same description as the coupe except that the top is collapsible. There is only one movable glass window on each side. The rear quarters and back above the belt and the roof are covered with leather or imitation leather. The front pillars or windshield standards are fixed. The doors are of the landau type with flappers or folding upper frames and the top back of the front pillars is entirely collapsible.

Limousine—A partially enclosed body with a fixed roof that extends the full length of the body and is attached at the front to the windshield standards. Only the rear section of the body forward to the partition at the rear of the driving seat is fully enclosed; forward of this point the sides are enclosed only from approximately the belt downward. There are two low doors and one fixed cross seat for two in the forward section. In the rear section there is one fixed cross seat for two or three and sometimes two emergency collapsible seats. There are two doors in the rear section and two movable glass windows on each side.

Brougham—A body of the same general description as the limousine, except that the fixed roof extends over only that section of the body that is entirely enclosed.

The brougham as originally used on carriages had only one movable glass window on each side. Occasionally, it is made this way for passenger cars.

Landau and landaulet bodies have been superseded or used in combination with other types, because the true landau does not have a sufficient body length for passenger-car use. The coupelet is a landaulet with the exception that the manner of folding the portion of the roof rail over the door is made with a different hinging arrangement and the front pillars are fixed. The cabriolet has superseded the landau, but it is different in that the falling-pillar hinge has a large swinging radius and therefore permits the rear section to be large enough for present uses. Both the coupelet and the cabriolet make use of the landau type of door, whereas the combinations, limousine-landaulet and brougham-landaulet, make use of the landau falling-pillar hinge, but do not use the landau type of door.

Limousine-Landaulet—A body of the same general description as the limousine, except that the top back of the rear doors is collapsible. Forward of these doors the roof is fixed and the windows are the same in number as for the limousine. The rear quarters and back above the belt and the roof are covered with leather or imitation leather.

Brougham-Landaulet—This type of body has the same relation to the brougham that the limousine-landaulet has to the limousine.

Cabriolet—A partially enclosed body, the two sections being the same as with the brougham. The roof and the pillars forming the partition are fully collapsible. The rear doors are of the landau type with either flappers or folding upper sections. There is one movable glass window on each side. The rear falling-pillar hinge has its center located far enough back from the face of the pillar to throw the top when falling back of the rear bar and the parting-line from the pillar face to the hinge center is generally a segment of an oval and shows plainly. The rear quarters and back above the belt and the roof are covered with leather or imitation leather and the back and side roof corners in the conventional design have a larger radius than in other types of closed body. The interior seating arrangements are for two or three passengers on one fixed cross seat and small folding seats on the partition for two facing back.

Town Car—This term is used for body types that are designed particularly for local use such as for shopping in cities and applies to chauffeur-driven cars only.

Passenger-Car Front-Axle Hubs

A Subdivision of the Axle and Wheel Division has been appointed to formulate a preliminary recommendation for front-axle hubs for passenger cars. The personnel of the Subdivision, known as the Passenger-Car Front-Axle Hubs Subdivision, is C. T. Myers, chairman, G. L. Lavery, R. B. Mudge, O. J. Rohde, F. W. Gurney, T. V. Buckwalter, A. M. Laycock and A. L. Putnam.

Protective Automobile Bumpers

The present S. A. E. Standard for protective bumpers for the front or rear of passenger-cars, page C55, S. A. E. Handbook, specifies a height from the ground to the center of the bumper face, definite overall lengths and a minimum vertical depth of the face.

It was recently suggested that the Society should undertake the standardization of the bumper brackets to permit interchangeability of bumpers or, what is more important, permit mounting bumpers without injury to the passenger-car frame or body. This subject was referred to the Parts and Fittings Division by the Council, a Subdivision appointed and, at the request of the Subdivision chairman, a general letter sent out to passenger-car builders asking their comment as to the feasibility of standardizing a plain bolted-on connection for the conventional type of passenger-car with a pressed-steel frame.

The replies to these circular letters indicate that the passenger-car builders are very much in favor of such standardization and the Subdivision plans to take immediate steps in formulating a recommendation.

Rating of Storage Batteries for Farm Electric Lighting Plants

One of the most vexing problems that has come before a Division of the Standards Committee is that of formulating a suitable standard method of rating electric storage batteries such as are used in connection with isolated electric lighting plants. After a somewhat protracted consideration of the subject at the request of interests in this branch of the automotive industries, a standard was adopted by the Society in August, 1919, which was published in the S. A. E. Handbook as follows:

> The standard battery rating shall be established at a standard (initial) temperature of 80 deg. fahr.
>
> The rated capacity of storage batteries shall be based on a final voltage of not less than 1.75 volts per cell for lead-acid batteries.
>
> The period of elapsed time at which the rated ampere-hour capacity is available shall be definitely stated.
>
> In rating batteries the maximum available capacity that can be obtained intermittently or over prolonged discharge periods shall be limited to that obtainable over a period of 72 hr.
>
> The standard test shall be at the rate of 1/24 of the ampere-hour capacity (72-hr. rating) of the battery for an initial period of 4 hr., followed by a 16-hr. rest, and then by two 8-hr. periods, each followed by a 16-hr. rest. After the last rest the final discharge period shall be 4 hr.
>
> All of the above is applicable to nickel-iron batteries, except the final voltage per cell, which applies to lead-acid batteries only. The short periods at the beginning and at the end of the test permit it to begin at noon of the first day and at noon of the last day.

It was thought at the time this standard was adopted that it would become generally used, but in the latter part of 1920 it was brought to the attention of the Standards Committee that the rating was not readily understood and had not proved acceptable. The matter was consequently again taken under consideration by the Isolated Electric Lighting Plant Division and at meetings held early this year a proposed new rating was recommended, which read:

SECTION 1

> The Isolated Electric Lighting Plant Division recommends that the present S. A. E. Standard "Rating of Storage Batteries" printed on page B37, Vol. I, S. A. E. Handbook, be cancelled.

SECTION 2

> Storage batteries for farm light and power purposes shall be rated in terms of the number of hours discharge capacity at a constant rate corresponding to 300 [*200*] watts, or fifteen [*ten*] 20-watt lamps.
>
> In determining isolated electric light and powerplant battery ratings, manufacturers shall conform with the following conditions:
>
> (1) The normal range of specific gravity which is recommended by the battery manufacturers for the batteries in service shall be used during tests.
>
> (2) Battery ratings shall be established at an initial temperature of cells not to exceed 80 deg. fahr.
>
> (3) The watts at which the rating of lead batteries is determined shall be based on a normal voltage of 2 volts per cell. The final voltage on continuous discharge shall not be less than 1.75 volts per cell.
>
> (4) The batteries to be tested shall not be charged more than 120 per cent (in ampere-hours) of the last previous discharge.
>
> (5) The resultant test shall indicate the number of hours of service lead-acid batteries will give when discharged at a constant rate corresponding to 300 [*200*] watts.
>
> [(6) *At 200 watts, 32 volts, the constant discharge rate shall be 6.25 amp.*]

In Section 2 the items included in the brackets were changes in the Division's recommendation which were requested at a meeting of the Farm Lighting Plant Section of the Gas Engine and Farm Power Association held in Chicago shortly after the meeting of the Division.

At the Standards Committee meeting in West Baden on May 24, Section 1 of the Division's recommendation was approved, and the standard adopted in August, 1919, has been cancelled. Section 2 of the recommendation was, however, referred back for further consideration by the Division and the lighting plant industry. Following the action taken at the Standards Committee meeting a historical review of the subject and the suggestions that had been received by the Society as to what would be an acceptable rating were sent to all members of the Division and most of the companies manufacturing plants or batteries which are not represented on the Division. A general meeting was then arranged for in Chicago on July 28, for the purpose of again endeavoring to formulate a recommendation for a standard that would be practical and receive, if possible, unanimous approval from the manufacturers. Those in attendance were

[1]William A. Biesmann, General Battery & Supply Co., Chicago.
[1]W. J. Burchill, Fairbanks, Morse & Co., Chicago.
L. F. Burger, International Harvester Co., Chicago.
R. S. Burnett, standards manager, Society of Automotive Engineers, New York City.
W. A. Chryst, vice-chairman, Standards Committee, Dayton Engineering Laboratories Co., Dayton, Ohio.
G. M. Gardner, Globe Electric Co., Milwaukee.
E. H. Harsher, D.-G. Storage Battery Co., Chicago.
L. W. Heath, Litscher-Lite Corporation, Grand Rapids, Mich.
[1]P. B. Hyde, General Battery & Supply Co., Chicago.
L. S. Keilholtz, chairman of the Division, Delco Light Co., Dayton, Ohio.
J. B. Livingston, Eagle Picher Lead Co., Cleveland.
[1]A. V. Morris, Electric Storage Battery Co., Philadelphia.
[2]J. N. Naiden, Prest-O-Lite Co., Inc., Indianapolis.
E. B. Newill, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.
[1]E. D. West, Fairbanks, Morse & Co., Chicago.
[1]Lloyd Yost, Fairbanks, Morse & Co., Chicago.

[1]Non-member of the Division.
[2]Non-member of the Division representing I. M. Noble, member of Storage Battery Division of Standards Committee.

Discussion at the meeting related largely to what had already been done by the members of the Division to formulate a suitable standard for commercial use that could be as readily understood and used by purchasers of these lighting plants as by the manufacturers, and the efforts made by the Division members to secure unanimous agreement to such a recommendation. More or less division of opinion among the manufacturers has been evident as to what a standard rating should be, but in carrying forward the work it has been the expressed purpose of the Division to come to as nearly unanimous agreement as possible. Since it does not at this time appear possible to come to a unanimous conclusion, it is believed that a recommendation that would be approved by a large majority of the plant manufacturers should be adopted. After considerable discussion in detail as to methods of rating and the comparative results of ratings for different types of lead-acid storage batteries, it was, upon motion of Mr. West, and the second of Mr. Newill, recommended, with 10 of those present voting, two dissenting votes being cast, one by a lighting-plant manufacturing company representative and the other by a representative of a battery manufacturing company, that the Isolated Electric Lighting Plant Division report to the Standards Committee the following method of rating farm lighting plant batteries for adoption as standard by the S. A. E.:

> The standard rating of capacity for lead-acid storage-batteries for use with isolated or farm electric lighting and power plants shall be expressed in terms of watt-hours based on a continuous 8-hr. discharge test at a nominal voltage of 2 volts per cell, the discharge not to be carried beyond a terminal voltage of less than 1.75 volts per cell. The initial temperature of the battery electrolyte on test shall not be more than 80 deg. fahr.

There was some discussion in connection with a proposal to have a double rating; one based on the former standard

72-hr. intermittent rating and the other as recommended above, but this did not meet with approval. After checking the proposed new rating to specific sizes of battery to illustrate its application in practice and further remarks in connection with the attitude that will probably be taken by manufacturers on its adoption, the meeting adjourned.

As there was not a quorum of the Division present, the new proposal will be submitted to a letter ballot of the Division and by correspondence to all the lighting-plant and battery manufacturers for approval or constructive criticism before it is reported to the Standards Committee and Society meetings next January. It was desired by those present at the meeting in Chicago on July 28 that the recommendation be given wide publication so that there will be general knowledge as to what the Division is trying to accomplish and manufacturers interested in the subject given an ample opportunity to participate in the establishment of such a standard rating. The Division requests that manufacturers of plants and batteries transmit by letter to the office of the Society their approval of the action taken and advices of their intention to adopt this rating, or their reasons for not approving it. In this way, the Division will have a direct means of knowing the sentiment of the whole industry and can be guided accordingly.

Taper Fittings With Plain or Slotted Nuts

The Parts and Fittings Division has recommended that the S. A. E. Standard for Taper Fittings With Plain or Slotted Nuts, page C14, S. A. E. Handbook, be revised by the addition of a footnote reading

> The center-line of the cotter-pin hole shall be 90 deg. from the position of the keyway as shown in the drawing

The addition of this note, which definitely specifies the location of the cotter-pin hole, will avoid any possible danger of question arising as to its location. At the present time this location is only shown in the drawing illustrating the standard.

Timer-Distributor Mountings

The present S. A. E. Type B Distributor Mounting, page B16, S. A. E. Handbook, specifies that the distance from the end of the tongue of the coupling to the end of the distributor body shall vary to suit conditions. It has recently been suggested that this distance should be definitely specified and that ⅞ in. would probably be in accordance with present practice.

This subject was discussed at the last meeting of the Electrical Equipment Division, but no definite action was taken as it was desired to base Division action on the consensus of opinion of the electrical equipment and engine manufacturers. A general letter was sent out and the information obtained turned over to W. A. Chryst, who was appointed a Subdivision of one to review the information and submit a recommendation for consideration at the next meeting of the Division.

AMERICAN CAR WINS GRAND PRIX

THE automotive engineers of this country cannot refrain from feeling rather jubilant over the recent victory of an American car and driver in the French Grand Prix at Le Mans. In accomplishing this feat Jimmy Murphy attained an average speed of 78.1 m.p.h. with his Duesenberg car over a course that is reported as very rough in spots, includes three right-angle turns and one turn whose included angle is 30 deg. Thirteen cars started in the race; four Duesenberg eights represented the United States, four Ballots carried the French colors, and four Talbots and a Mathis appeared for England. Out of these 13 starters 11 were equipped with 3-litre straight-eight engines. This fact is of engineering interest since it further defines the trend, first evidenced at Indianapolis, toward this engine type for racing work.

The engine of the winning car has eight cylinders 2½x4⅝ in. cast in a single straight block integral with the upper half of the crankcase. There are two exhaust-valves and one inlet-valve in each cylinder, operated by an overhead camshaft and mounted in a detachable head. The engine is shorter than most eight-in-line engines since the crankshaft is mounted on only three bearings. It is reported that these engines are capable of running as high as 5000 r.p.m. and that the power peak is reached at 4225 r.p.m. Two carbureters are used each serving a group of four cylinders.

The braking system is the outstanding feature of the chassis and proved advantageous on this difficult course. Brakes are fitted to all four wheels and are operated by hydraulic pressure which is transmitted through flexible tubing to the brake-actuating mechanism. A three-speed transmission is employed with central control.

This is the only American victory in the series of Grand Prix races, the first of which was run in 1906. Previous attempts have been made by the designers of this country to surpass the efforts of the Continental engineers and the ultimate success of the group of men who designed and built the cars and financed this recent invasion is viewed with warranted pride by all in the industry.

THE QUANTITY THEORY OF MONEY

THE amount of money in circulation has no direct effect on prices, but indirectly it has an enormous effect, since business cannot be transacted without money. In the same way neither can houses be built without materials and tools, and yet the mere existence of these latter will not bring about an era of building by their mere plentifulness unless all the other requisites are present. Moreover, an abundance of money and of credit, especially of credit, which is an entirely different thing from money, usually leads to speculation, which creates an artificial and temporary demand that for the time being puts up prices. This is the indirect effect. A still more convincing proof of the part money really plays is found in some European countries where there is apparently an endless volume of currency, of a depreciated type, and yet prices are falling. From now on, for a time at least, we shall probably see a decreasing volume of currency, not as a cause, but as an accompaniment and consequence of falling prices, since not so much money will be needed in the conduct of business, and Federal Reserve notes will be retired automatically from circulation so that there can be the necessary adjustment of supply and demand.—A. W. Douglas in *Administration*.

Publications of Interest *to* S. A. E. Members

In this column are given brief items regarding technical books and publications on automotive subjects. As a general rule, no attempt is made to give an exhaustive review of the books, the purpose of this section of THE JOURNAL being rather to indicate from time to time what literature relating to the automotive industry has been published with a short statement of the contents.

STANDARDS FOR TESTING WELDS. American Welding Society Bulletin No. 1. Published by the American Welding Society, 33 West Thirty-ninth Street, New York. 16 pages.

The chief difference between testing a specimen of steel that includes a welded joint and testing an ordinary specimen is the non-homogeniety of the welded specimen. The welded specimen has at its center, a section composed of material that usually has physical, chemical and metallurgical characteristics distinctly different from the adjoining metal. Furthermore, the section of the added metal is more or less irregular in shape and of variable size. Consequently the procedure prescribed for testing ordinary specimens is not applicable to those containing welded joints. Although more thorough research work in this field may develop more satisfactory standards for tests of welds, the need for some immediate standards is so great that the universal use of these specifications is urged upon all those who have to do with the testing work in this field.

REPORT ON 170-HP. ABC WASP RADIAL AERONAUTICAL ENGINE. Air Service Information Circular Vol. II, No. 167. Published by the Chief of Air Service, Washington. 23 pages.

This report which illustrates and describes the ABC Wasp engine of British construction, includes also weight, dimensional and performance data. The performance with regard to power, economy and cooling was the best obtained by the engineering division of the Air Service on any stationary radial air-cooled engine of over 100 hp.

AERODYNAMIC CHARACTERISTICS OF AIRFOILS. National Advisory Committee for Aeronautics Report No. 93. Published by the National Advisory Committee for Aeronautics, Washington. 81 pages.

This report brings together the investigations of aerodynamic laboratories of this country and Europe upon the subject of airfoils suitable for use as lifting or control surfaces on aircraft. The data have been arranged so as to be of the most use to designing engineers and for purposes of general reference. Curves are presented from which the airfoil coefficients can be read with sufficient accuracy for design purposes. The dimensions of the profile of each section are given at various stations along the chord in per cent of the chord. In order that the designer can select easily a wing section suited to a particular type of machine, four index charts are given that classify the wings according to their aerodynamic and structural properties.

DEFLECTION OF BEAMS OF NON-UNIFORM SECTION. Air Service Information Circular Volume III, No. 213. Published by the Chief of Air Service, Washington. 10 pages.

This report explains and illustrates a graphical and analytical method of calculating the deflection of beams of non-uniform section. The method is based on the familiar area-moment theorem and is applicable to many structural design problems in automotive work such as frame side members and airplane spars.

MEASUREMENT OF IMPACT OF MOTOR TRUCKS ON ROADS. By Earl B. Smith. Paper read before the American Society for Testing Materials, 1315 Spruce Street, Philadelphia. 8 pages.

The author describes and compares two methods developed in the laboratories of the Bureau of Public Roads for measuring the road impact of motor-truck wheels. In the method designated as the "autographic method" a mechanism is provided which records the space-time curve of the vertical movement of the truck wheel. By a process of differentiation a deceleration-time curve is constructed from this and the impact force calculated. In the second or "deformation method" the impact force compresses a small copper cylinder. The resulting deformation when compared with that of a similar cylinder compressed statically serves as a measure of the impact force.

THE 300-HP. BENZ AIRCRAFT ENGINE. By Dr. A. Heller. National Advisory Committee for Aeronautics Technical Note No. 34. Published by the National Advisory Committee for Aeronautics, Washington. 17 pages.

This description, translated from the *Zeitschrift des Vereines Deutscher Ingenieure*, outlines the features of the 12-cylinder, 60-deg. V-type, 135 x 150-mm. (5.315 x 5.906-in.), Benz aircraft engine. Detail drawings show the cylinder construction, valve gear, connecting-rods, piston, oil and fuel system units and the general assembly. Performance data are not given.

AUTOMOTIVE IGNITION SYSTEMS. By E. L. Consoliver and G. I. Mitchell. Published by McGraw-Hill Book Co., New York City. 269 pages; 345 illustrations.

This volume illustrates and describes in an elementary way the principles and construction of the modern electric ignition system for automotive engines. Although intended primarily for the man who installs or repairs ignition apparatus, it should assist the automotive engineer whose knowledge of ignition systems is limited, to become familiar with their essential details and operation. Chapters are devoted to the simple principles of electricity and magnetism, storage batteries, battery-ignition systems and high and low-tension magnetos. The care and repair of ignition apparatus are treated and the means of correcting ignition troubles given.

THE DYNAMOMETER HUB FOR TESTING PROPELLERS AND ENGINES DURING FLIGHT. Translated from *Zeitschrift für Flugtechnik und Motorluftschiffahrt.* National Advisory Committee for Aeronautics Technical Note, No. 59. Published by the National Advisory Committee for Aeronautics, Washington. 18 pages.

A dynamometer hub that measures and records the torque and thrust of a propeller while in flight is described and illustrated. This was developed at Adlershof, Germany, during the war by the staff of the aeronautical laboratory. Observed results of flight tests are presented and analyzed.

EXPERIMENTAL REINFORCED PLYWOOD TRUSS RIBS. Air Service Information Circular Vol. III, No. 212. Published by Chief of Air Service, Washington. 17 pages.

This report summarizes the work that has been done by the Air Service on the development of reinforced plywood truss ribs for airplane wings and compares this type of rib with other types. The comparisons show that the reinforced plywood truss type of rib construction is probably superior to any other type of wood construction so far developed. The simplicity and low production cost of this rib are its most essential features, although it is very stiff and rigid in comparison with other types.

CAMS, ELEMENTARY AND ADVANCED. By Franklin DeR. Furman. Published by John Wiley & Sons, New York City. 234 pages; 182 illustrations.

The principal interest of the automotive engineer in this book lies in its treatment of the several types of cams commonly used in the operating mechanism of poppet valves. Velocity and acceleration diagrams are constructed to show

the characteristic action of cams having different forms of base curves. Study of the diagrams enables the designer to select the type best suited for his particular need since comparison readily shows which form is best adapted for gravity, spring or positive return, and which is best for slow or fast velocities at various points in the stroke. The major part of the book is devoted to this discussion of cams for the conversion of rotary to vertical lift motion, although other miscellaneous actions and constructions are described, including the one where a rocker arm is interposed between the cam and lifter.

CALIBRATION OF CARBURETER JET FLOW. Air Service Information Circular Vol. III, No. 243. Published by the Chief of Air Service, Washington. 19 pages.

It has been recognized for some time that many of the discrepancies in carbureter performance can be traced to the use of improperly sized jets and more especially to the variation in flow of jets of the same nominal orifice size and shape. The object of this test was to determine the extent of this latter variation and obtain standard flow calibration curves for certain airplane carbureter jets. The test showed that a large variation in flow exists in carbureter jets of the same nominal orifice size, especially those soldered and drilled, and it is recommended therefore that all jets be calibrated by the use of a flow meter.

INVESTIGATION OF JUNKER BIPLANE WINGS. Air Service Information Circular Vol. III, No. 230. Published by the Chief of Air Service, Washington. 15 pages.

This report covers an exhaustive investigation of the wing and control plane structures of the Junker internally-braced monoplane. Physical properties and chemical composition of the duralumin used are given and the design and construction of the wings analyzed. It was concluded that the Junker wings are good examples of practical all-metal airplane construction. The duralumin tubing had an average ultimate tensile strength of 50,000 lb. per sq. in. and contained 94.6 per cent of aluminum, 3.34 per cent of copper, 0.81 per cent of iron and lesser quantities of silicon, magnesium and manganese.

THE ENGINEERING INDEX FOR 1920. Published by the American Society of Mechanical Engineers, New York City. 586 pages.

About 700 engineering periodicals, representing those not only of France, England and Germany, but even of Africa, India, Japan, Belgium and others, have been reviewed and indexed in the Engineering Index for 1920. The alphabetical arrangement of the 1919 Index, which marked such a decided improvement over the former group or sectional arrangement, has been retained in this new issue. The descriptive paragraphs after each reference continue to be a valuable feature because of the economy of time that can be effected in making a research study. The automotive engineering field is very well covered and numerous references are noted on carbureters, fuels, engines and production methods. Any one of the articles indexed can be purchased in photostat form from the Engineering Societies Library, 29 West 39th Street, New York City.

GASOLINE AND OTHER MOTOR FUELS. By Carleton Ellis and Joseph V. Meigs. Published by D. Van Nostrand Co., New York City. 700 pages; 206 illustrations.

The student of the engine-fuel problem will find this volume a valuable addition to his library. The major part of the book describes the different distillation and refinery methods for the production of gasoline, including the several cracking processes. The means of condensing hydrocarbons from gases for the production of casinghead gasoline are illustrated and the manufacture of benzol described. Chapters are devoted to the use of benzol, alcohol and mixed fuels in internal-combustion engines and the accepted methods for testing fuels are given. The appendices include statistical data on production and consumption, a table of chemical and physical constants for hydrocarbon gases and vapors, and a study of the production of gasoline from natural gas.

BLACK NICKEL PLATING SOLUTIONS. By George B. Hogaboom, T. F. Slattery and L. B. Ham. Technologic Paper of the Bureau of Standards No. 190. Published by Government Printing Office, Washington. 9 pages.

To produce the gun-metal finish on military hardware, "black nickel" plating was frequently applied. Investigation showed that for this purpose very complicated solutions were frequently employed, and at times great difficulty was encountered in producing uniform results. This paper describes the results of a few experiments on such solutions and contains recommendations regarding the composition and conditions of operation that will yield satisfactory deposits upon brass, copper and zinc; upon brass plated with copper; and upon steel plated with copper, nickel, or zinc. This type of plating is applicable to automotive parts where a dark finish is desirable.

AIRPLANE PERFORMANCE AND DESIGN CHARTS. Prepared by the Engineering Division of the Air Service. Air Service Information Circular Vol. II, No. 183. Published by the Chief of Air Service, Washington. 23 pages.

This report describes an empirical-theoretical method of predicting from graphical charts the performance of an airplane whose weight, area, horsepower and external characteristics are known and, by corollary, a method for determining the weight and area of an airplane of given horsepower and external characteristics that is to be designed to realize a particular performance.

TRANSACTIONS OF THE SOCIETY FOR 1920

THE members will soon receive bound copies of the TRANSACTIONS of the Society for the first half of 1920. This volume has been in process for some time, having been delayed by an extended printers' strike.

The volume just completed is the largest in point of text pages and is the fifteenth to be issued by the Society. There is a total of 1083 pages exclusive of the general index, this comparing with 798 pages in Part 1, 1919, the next largest half-yearly volume.

The major part of the text matter is made up of automotive engineering papers of permanent value, most of which were contributed by members at Society and Sections meetings. There are 46 technical papers in all and they cover the several automotive fields in which the members are engaged. A classification shows that six papers relate to fuel matters, eight to cars and trucks, eight to aviation, six to engines, five to tractors, three are on marine subjects, and ten cover general subjects. Most of the papers are illustrated with drawings, photographs and curves making them especially clear and valuable to the members for reference purposes.

The report of the Standards Committee for January, 1920, occupies 65 pages. The Division reports serve as a permanent record of the progressive work done by the Standards Committee in the last half of 1919 and are accompanied in each case by the necessary tables or diagrams to illustrate the Standards or Recommended Practice as adopted.

LAST ADDRESS OF MEMBERS NEEDED

Members who contemplate changing their mail address or have already done so should be especially careful to notify the Society offices in New York City in view of the possibility of this valuable volume not reaching them.

All members who paid dues for the period covered by Part 1 1920 TRANSACTIONS are entitled to copies of it. The price of the volume to non-members is $10.

Applicants *Qualified*

The following applicants have qualified for admission to the Society between July 10 and Aug. 10, 1921. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

BANCROFT, FLOYD C. (A) technical field representative, Locomobile Co., *Bridgeport, Conn.,* (mail) 2679 Main Street.

BARTLETT, LINTON G. (M) vice-president and chief engineer, O'Connell Motor Truck Co., *Waukegan, Ill.*

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BEST, HARRY A. (A) sales representative, Sheldon Axle & Spring Co., Wilkes-Barre, Pa., (mail) 4933 North Kedzie Avenue, *Chicago.*

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BOONE, CAPT. MILTON O. (S M) Quartermaster Corps, (mail) *Camp Sherman, Ohio.*

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CLOYD, P. C. (M) Willard Storage Battery Co., 2524 South Wabash Avenue, *Chicago.*

CONANT, DAVID J. (A) mechanical engineer and chief engineer, Western Well Works, Inc., 522 West Santa Clara Street, *San Jose, Cal.*

DARNELL, REX C. (M) assistant chief engineer, Northway Motor & Mfg. Co., *Detroit.*

DE MARINGH, ALBERT F. (A) sales engineer, Marburg Bros., Inc., New York City, (mail) 1237 Jarvis Avenue, *Chicago.*

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DOMONOSKE, ARTHUR B. (M) assistant professor of mechanical engineering, University of California, 32 Mechanics Building, *Berkeley, Cal.*

EYMAN, ERNEST E. (A) sales agent, National Malleable Castings Co., 10600 Quincy Avenue, *Cleveland.*

FULDA, RENE (F M) director, Société Française des Automobiles White, *Paris, France,* (mail) 82 Boulevard Flandrin.

HEWITT, CLARENCE C. (A) special factory representative, Tide Water Oil Co., New York City, (mail), 44 Garfield Building, *Detroit.*

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HUENING, C. L. (A) in charge of specification division, Mitchell Motors Co., Inc., *Racine, Wis.,* (mail) care Engineering Department.

HUTCHINSON, ROLAND V. (M) designing engineer, mechanical engineering section, General Motors Research Corporation, *Dayton, Ohio,* (mail) 2000 Melrose Avenue.

INFIORATI, M. E., JR. (A) chief engineer and assistant general manager, J. N. Lapointe Co., *New London, Conn.,* (mail) 104 Ocean Avenue.

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KIMBALL, EARL W. (A) vice-president and service manager, Ostendorf Motor Car Corporation, *Buffalo,* (mail) 168 Wellington Road

KING, ALEXANDER H. (M) mechanical engineer and designer, Aeromarine Plane & Motor Co., *Keyport, N. J.*

KING, HAROLD L. (J) mechanical draftsman, Syracuse Engineering Office, Ordnance Department, *Syracuse, N. Y.,* (mail) 216 Erie Street.

KINGSTON, CHARLES T. (A) manager, John Brennan & Co., *Detroit,* (mail) 4262 Seebaldt Avenue.

LANE, F. VAN Z. (M) general maintenance manager, Hare's Motors, Inc., 16 West 61st Street, *New York City.*

LIPPERT, R. E. (A) sales engineer, Drying Systems, Inc., *Chicago,* (mail) 5530 Wayne Avenue.

LOVEN, OTTO H. (J) Park Heights Garage, *Locust Valley, N. Y.*

MCALPIN, KENNETH (A) manager, Motor Products Sales Co., *Seattle, Wash.,* (mail) 3415 East Howell Street.

MCCAULEY, J. E. A. (A) chief engineer, Hayes Wheel Co. of Canada, *Chatham, Ont., Canada,* (mail) Hotel Sanita.

MCKINNON, ERNEST C. (F M) Chloride Electrical Storage Co., Ltd., *Clifton Junction, near Manchester, England.*

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MACDONALD, LACHLAN M. (A) vice-president and general manager, Bryan Pattern & Machine Co., Bryan, Ohio, (mail) *Wauseon, Ohio.*

MIXSON, ROBERT E. (J.) aeronautical engineer, National Advisory Committee for Aeronautics, Langley Field, *Hampton, Va.,* (mail) 164 Melrose Avenue.

MOODEY, A. W. (A) engineer, Sherwin-Williams Co., 34 South Meridian Street, *Indianapolis.*

MOORE, WHITLEY B. (J.) sales engineer, Timken Roller Bearing Co., Canton, Ohio, (mail) 450 Monadnock Building, *San Francisco.*

MUHLON, EDWARD (A) 313 West 134th Street, *New York City.*

MURRAY, MAJOR MAXWELL (S M) Office of the Chief of Field Artillery, *Washington,* (mail) 1742 R Street.

NAIDEN, JAMES HENRY (M) director of laboratories, Prest-O-Lite Co., Inc., *Indianapolis.*

NATIONAL STEEL CAR CORPORATION, LTD., (Aff) *Hamilton, Ont., Canada.*
Representative:
Cartzdafner, R. E.

PARDEE, HOMER A. (A) vice-president and general manager, Halcomb Steel Co., *Syracuse, N. Y.*

PENGILLY, H. EUGENE (M) mechanical engineer, chief of motor carriage section, Ordnance Department, Washington, (mail) 112-15 St. Anns Avenue, *Richmond Hill, N. Y.*

PETERSON, GUSTAF (A) general manager of sales, Electric Alloy Steel Co., *Youngstown, Ohio.*

PETIT, HENRI (F M) engineer, Vie Automobile, Paris, (mail) 42 Rue Brancas, *Sevres (Seine et Oise) France.*

PIKE, WALTER L. (J) engineering department, Cleveland Experimental Laboratories Co., 1444 East 49th Street, *Cleveland.*

PRICHARD, LEONARD W. (E S) student, Tri-State College of Engineering, Angola, Ind., (mail) *Mount Vernon, Iowa.*

RUSSOM, DOUGLAS A. (J) development and experimental engineer, International Harvester Co., *Chicago,* (mail) 4012 West Jackson Boulevard.

SELMAN, EDWARD C. (A) member of president's technical staff, Pierce-Arrow Motor Car Co., 1695 Elmwood Avenue, *Buffalo.*

SEWARD, WALTER E. (A) technical school director, Y. M. C. A., *Canton, Ohio.*

SPEER, MODISETTE BRUCE (A) superintendent, automobile equipment service department, Westinghouse Electric & Mfg. Co., *Springfield, Mass.,* (mail) 120 East Alvord Street.

STEINBECK, PAUL W. (M) body engineer, H. H. Babcock Co., *Watertown, N. Y.,* (mail) 608 Sherman Street.

STEWART, ELLIOTT W. (M) spring engineer, William D. Gibson Co., 1800 Clybourn Avenue, *Chicago.*

TAIT, WILLIAM O., JR. (J) experimental testing engineer, International Motor Co., New York City, (mail) 476 Rossmore Avenue, *Bronxville, N. Y.*

THEARLE, ERNEST L. (M) instructor, mechanical engineering, Sibley College, Cornell University, Ithaca, N. Y., (mail) Wanakena Camp, *Pilot Knob-on-Lake George, N. Y.*

WEED, HUGH H. C. (M) first vice-president and general manager, Carter Carbureter Co., 2838 North Spring Avenue, *St. Louis.*

WHITALL, LAWRENCE W. (A) consulting engineer, Industrial Properties Corporation, *Louisville, Ky.,* (mail) 1810 South Third Street.

WERNEKEN, FRANK E. (A) secretary and treasurer, John Brennan & Co., *Detroit,* (mail) P. O. Box 683.

WILLIAMS, G. M. (M) general manager, Dayton Wright Co., *Dayton, Ohio.*

WYLIE, ARTHUR R. (M) patent attorney, Dyrenforth, Lee, Chritton & Wiles, 1508 Marquette Building, *Chicago.*

Applicants *for* Membership

The applications for membership received between June 30 and Aug. 15, 1921, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ANDERSON, F. W., vice-president and general manager, North Western Motor Co., *Eau Claire, Wis.*

BALKAM, HERBERT H., draftsman, Briscoe Motor Corporation, *Jackson, Mich.*

BERLIET, MARIUS, general manager, Societe des Automobiles, M. Berliet, *Lyons, France.*

BLAKESLEE, HERBERT, sales engineer, Splitdorf Electrical Co., *Newark, N. J.*

BUQUOR, A. P., production manager and experimental work, Compania Automoviles Anahuac de Mexico, *Indianapolis.*

CALKINS, ADDISON N., superintendent, Electric Wheel Co., *Quincy, Ill.*

CHILMAN, H. LEA, commercial transport consultant, Victoria Park, *Manchester, England.*

CORDES, JOHN, research engineer, Zenith Carburetor Co., *New York City.*

CORSON, BOLTON L., experimental engineer, H. H. Franklin Mfg. Co., *Syracuse, N. Y.*

CURTIS, PAUL R., 210 Arlington Street, *Wollaston, Mass.*

DANVILLE MALLEABLE IRON CO., *Danville, Ill.*

DESCHAMPS, RENE, works manager Minerva Motors, Ltd., *Antwerp, Belgium.*

DEWAIDE, HAL, custom body designer, Hal DeWaide Sport Cars, *Portland, Ore.*

DORIOT, GEORGES F., Doriot, Frandrin, Parant, Courbevoie, France, 14 Story Street, *Cambridge, Mass.*

ERSKINE, JAMES E., chief engineer, Perfection Engineering Products Corporation, *Jacksonville, Fla.*

FISH, MELVIN L., automotive designer, engineering office, Ordnance Department, *Syracuse, N. Y.*

FISHER, CARL HERBERT, assistant service manager, General Motors, Ltd., *London, England.*

GIRSCHIG, H., engineer, Society Dietrich a Argenteuil, *Neuilly, Seine, France.*

GRAPES, G. HAMILTON, managing director and chief engineer, Austral Motors, *Melbourne, Australia.*

HAMM, HARRY L., automotive instructor, Air Service Mechanics School, *Rantoul, Ill.*

HANLON, LAWRENCE F., sales engineer, Acme Die-Casting Corporation, *Brooklyn, N. Y.*

HEINSS, CHRISTIAN F., SR., president, Big Farmer Corporation, *Fort Madison, Iowa.*

HERRICK, EDWARD D., assistant chief engineer, Lycoming Motors Corporation, *Williamsport, Pa.*

HERON, S. D., aeronautical mechanical engineer, powerplant section, Air Service, McCook Field, *Dayton, Ohio.*

HOBART, JOHN P., JR., designer, Union Gas & Electric Co., *Cincinnati.*

HOLMES, FRANK E., head machinist, Walter M. Murphy Motors Co., *Pasadena, Cal.*

JACKSON, ELWELL R., automotive engineer, Rock Island Arsenal, *Rock Island, Ill.*

JOHNSON, FRED V., consulting engineer, Avery Co., *Peoria, Ill.*

JOHNSON, JOHN E., assistant chief draftsman, Reo Motor Car Co., *Lansing, Mich.*

KAHN, FRANK, aeronautical draftsman, Naval Aircraft Factory, *Philadelphia.*

KERSHOW, W. V., export service correspondent, J. N. Willys Export Corporation, *Toledo.*

KING, KENNETH J., student, University of Wisconsin, *Madison, Wis.*

KOPPIN, BENJAMIN L., truck designer, Erie Motor Truck Co., *Erie, Pa.*

LEAMY, J. M., power commissioner, Government of Province of Manitoba, *Winnipeg, Man., Canada.*

MCGRATH, JOHN, assistant treasurer, Eberhard Mfg. Co., *Cleveland.*

MCKINLEY, WILLIAM A., engineer, Detroit Pressed Steel Co., *Detroit.*

MACLEAN, ALLEN D., engineer, New Departure Mfg. Co., *Bristol, Conn.*

MARSHALL, LEWIS C., president, Pressure Proof Piston Ring Co., *Boston.*

MITCHELL, ALBERT F., engineer, tank, tractor and trailer division, Ordnance Department, *Washington.*

MORAN, CHARLES B., engineer, American Die & Tool Co., *Reading, Pa.*

MOTTINGER, BYRON T., chief engineer, Quaker City Rubber Co., *Wissinoming, Philadelphia, Pa.*

MURDOCK, FREDERICK R., assistant engineer, Elgin Motor Car Corporation, *Argo, Ill.*

REID, ALBERT R., chief chemist, United States Light & Heat Corporation, *Niagara Falls, N. Y.*

REINHARD, LOUIS, engineer, Geuder, Paeschke & Frey Co., *Milwaukee.*

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SCHAUFELE, WILLIAM H., JR., layout draftsman, O. Armleder Co., *Cincinnati.*

SHARPE, C. H. F., inspector, General Motors Export Co., *New York City.*

SMITH, GEORGE W., designing draftsman, Ainsworth Mfg. Co., *Detroit.*

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THOKE, A. R., superintendent, Gearless Motor Corporation, 117 Flavel Street, *Pittsburgh.*

TILDEN, SYDNEY G., in charge of wholesale sales, Vandar Motor Sales Corporation, *Brooklyn, N. Y.*

WADDINGTON, CLIFFORD W., transportation supervisor, Great Atlantic & Pacific Tea Co., *Jersey City, N. J.*

WAMPLER, HOMER H., owner, Dayton Automotive Specialty Co., *Dayton, Ohio.*

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

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Coming Society Meetings

THE Meetings Committee has completed its schedule of national meetings for the 1921-1922 season and is engaged in the arrangement of the program details. The activity of the Society in the meetings field is to be maintained on the same basis is in the past notwithstanding industrial conditions. The coordination of thought and effort centered in engineering meetings has an economic value that cannot be measured readily, but is recognized as an important factor in our industrial and national life. Times like the present accentuate this value and the Council and the Meetings Committee plan to maintain a more aggressive policy than ever before to make the coming sessions of the greatest possible benefit to the members and the whole automotive field.

Visit to Aberdeen Proving Ground

General Williams' invitation to the Society to visit Aberdeen Proving Ground will be accepted by a great many members. The Metropolitan, Pennsylvania and Washington Sections are making this event the occasion of their October gatherings, and a number of members from more distant points have signified their intention of being present.

The program will fill the entire day and consist of firing tests and demonstrations of guns, armor-plate, projectiles, aerial bombs, aircraft, machine-guns and mobile mounts. The Army Ordnance Association will hold its annual convention at this time and members of the American Society of Mechanical Engineers interested in ordnance development have been invited to attend. There will, therefore, be present a most notable group of those to whom the Army will look for engineering cooperation in the event of need. On Saturday, Oct. 8, the Society's Ordnance Advisory Committee will hold a session at the office of the technical staff of the Ordnance Department in Washington.

At Aberdeen, beginning at 9:40 a. m. Friday, Oct. 7, and until 8 in the evening, every minute will be filled with interesting events. The program will be substantially as follows:

(1) Firing of tracer ammunition from Browning machine-guns against free balloons
(2) Firing of new design 0.50 caliber machine-gun
(3) Firing of mobile guns varying from 75 mm. (2.95 in.) to 9.20 in. in caliber, mounted on various types of carriage
(4) Demonstration of 75-mm. (2.95-in.) gun and 105-mm. (4.13-in.) howitzer on Christie motor carriages with removable tracks
(5) Demonstration of 75-mm. (2.95-in.) gun and 105-mm. (4.13-in.) howitzer on Holt motor carriages that it is claimed can make 30 m.p.h.
(6) Demonstration of tractor-drawn gun cariages versus self-propelled carriages
(7) Demonstration of 155-mm. (6.102-in.) gun or 8-in. howitzer Mark IX Holt motor carriage
(8) Demonstration of 3.7-in. anti-aircraft gun on Christie mount
(9) Demonstration of 4.7-in. anti-aircraft gun on Christie mount
(10) Demonstration of 2½,, 5 and 10-ton caterpillar tractors
(11) Demonstration of Peoria reconnaissance tractor
(12) Demonstration of Militor truck equipped with Chase track
(13) Demonstration of Dodge truck equipped with Chase track
(14) Demonstration of small, medium and large tanks
(15) Dropping of 2000 and 4000-lb. bombs from airplanes. This is one of the main features of the program
(16) Dropping of 600-lb. bombs with instantaneous functioning and with delay-action fuses. This is one of the main features of the program
(17) Examination of collection of foreign ordnance materiel, including 42-cm. (16.5-in.) German howitzer
(18) Examination of mobile ordnance-repair-shops
(19) Demonstration of machine-gun firing from airplanes. This demonstration will be made on the grounds at the aviation field and show the operation of the synchronizing device that permits firing through the propeller
(20) Exhibition of all types of United States and foreign bombs
(21) Exhibition of various types of airplane adapted to carrying bombs
(22) Exhibition of the C-2 dirigible airship
(23) Firing of 16-in. 50-caliber gun from barbette mount. This feature of the program is very unusual
(24) Firing of 16-in. 50-caliber gun from disappearing mount
(25) Examination of armor-plate that has been pierced by projectiles
(26) Examination of projectiles that have gone through armor-plate
(27) Examination of instruments used in obtaining the

velocity of projectiles that utilize the making, breaking or inducing of an electric current
(28) Firing of 14-in. railroad mount

There will be a 1-hr. intermission for luncheon and the demonstrations will be concluded in time for dinner, after which a smoker will be held and a number of short talks given.

It will be necessary for the Commanding Officer to engage an outside caterer to provide luncheon and dinner, the combined cost for which will be, it is estimated, about $3. Members who intend to be present should notify the Commanding Officer, Aberdeen Proving Ground, Aberdeen, Md., at once, in order that he may make the necessary mess arrangements. A check for $3 should accompany the letter. As a definite guarantee must be given to the caterer, no meals will be provided except for those who have previously notified the Commanding Officer.

Army regulations provide that admission to the Proving Ground be limited to citizens of the United States, excepting those who are engaged in the manufacture of munitions for foreign governments which are at war. As a means of identification and a pass to secure entrance into the reservation, members are requested to wear upon their arrival at Aberdeen and throughout the period of the meeting a tag that will be sent upon application to the office of the Society, 29 West 39th Street, New York City.

Special cars from New York City will be attached to the Baltimore & Ohio Railroad train leaving Pennsylvania Station at 1:00 a. m. Oct. 7. These cars will be ready for occupancy after 10:00 p. m. Thursday night. At Philadelphia these special cars will be detached and placed on the train with the Philadelphia contingent leaving at 7:45 a. m., stopping at Wilmington at 8:20 and arriving at Aberdeen at 9:10 a. m. Breakfast on the train.

A train will leave Washington at 7:45 a. m. and Baltimore at 8:40 a. m., arriving at Aberdeen at 9:24 a. m.

In the evening a train will leave Aberdeen at 8:37, reaching Wilmington at 9:25 p. m. and arriving at Philadelphia at 10:00 p. m. It will be possible to reach New York City late this same evening, depending somewhat upon train connections in Philadelphia.

A train will leave Aberdeen at 8:26 p. m., arriving at Baltimore at 9:03 p. m. and Washington at 10:05 p. m.

A number of members will probably drive to Aberdeen and they should arrange to be there at a time not later than the arrival of the trains.

Due to the lack of suitable facilities, it will be impossible to include ladies in this trip.

The Annual Meeting

The Annual Meeting of the Society will be held at New York City, Jan. 11-14, 1922, during the week of the New York Automobile Show. This arrangement is in accordance with precedent and is based on the knowledge that a large number of the members come East to visit the Show and study the exhibits. Sessions of the Standards Committee will be held on the morning and afternoon of Tuesday, Jan. 11. Many interesting and important reports are to be presented and discussed preparatory to their submission to the members for letter ballot on the adoption of standards and recommended practices. The technical session devoted to aeronautics will be held Tuesday evening, when it is proposed to have papers read on the latest engineering developments in this field. Reports of the executive officers for the year 1921 will be presented at the business meeting, Wednesday morning, and the result of the ballot for the election of officers for 1922 announced. Immediately following this H. M. Crane, chairman of the Research Committee, and Dr. H. C. Dickinson, will address the members on the work of the recently organized Research Department.

The broadened field of the Society's work necessitates the continuance of the holding of simultaneous sessions on those automotive engineering subjects whose scope does not overlap. Even with this arrangement it has been considered advisable to continue the professional meetings into Friday morning in order that the most important topics can be presented adequately.

On Wednesday afternoon three meetings will be conducted simultaneously on Body Engineering, Lubrication and Commercial Vehicles. There will be only one session on Thursday morning, when the subject will be Automotive Research. The Committee hopes to have an address made at this time by an engineer of international standing outlining certain experiences in automotive research abroad that confirm the increasing faith in industrial research as a paying investment. Thursday afternoon will be occupied by simultaneous meetings on Engines and Automotive Materials. The former will include fuel as well as engine papers. It is the purpose of the materials meeting to acquaint the members with metallurgical development since the war. A Passenger-Car Session will be held Friday morning, at which the chassis-design topics of greatest engineering interest will be discussed. Among these will be brake mechanisms and brake-lining materials.

The Carnival that has endeared itself to the members of the Society will be held on Wednesday evening, Jan. 11, starting at 10:30 p. m. The features of this event will be held in secret status by the committee as in the past. The element of surprise has proved an essential factor in past successes and for this reason the arrangements will not be disclosed beforehand.

The Annual Dinner has been set for Thursday evening, Jan. 12, and will at least maintain the standard of past years that has made this occasion institutional in character. C. F. Kettering gave his promise last January to repeat as toastmaster and our members appreciate the fact that this insures a lively evening.

Chicago Meeting

The Chicago Meeting of the Society will be held at the Hotel Drake, Feb. 1, 1922. There will be technical meetings in the morning and afternoon devoted principally to the problems of the operation and maintenance of automotive vehicles. The Chicago Dinner will be held at the Drake on the evening of the same day.

HIGHWAYS

THE bald statement, not infrequently heard, that considering their short life and the money invested in them, our new highways are economic failures, is, of course, untrue, but it contains enough of the truth to challenge our serious consideration and our best efforts to make it groundless in the future. Within certain limitations we should be able and the public may reasonably expect us to design and construct highways with something like the same success and certainty of results that characterizes our work in other departments of engineering.—S. Whinery.

Methods of Gear Design and Gear-Cutting

By Glenn Muffly[1]

Cleveland Section Paper *Illustrated with* Photographs and Diagrams

AFTER mentioning primitive forms of gears and stating the necessity for developing a tooth curve that would transmit uniform motion, the author describes and illustrates the cycloidal form of tooth and then considers the method of laying out involute gear teeth, this form having been adopted so that a constant pressure-angle or straight-sided form of rack tooth might be used.

The two methods of specifying gear-tooth sizes are illustrated and described, followed by a detailed discussion of the subjects of gear-hobs and gear-hobbing. Helical and worm gears are considered in similar style, inclusive of helical and worm-gear calculations and the hobbing of helical and worm gears. Numerous illustrations relating to each subject are presented and the paper is concluded by a brief description of ring-type thread-milling, which is sometimes confused with gear hobbing.

IN considering any pair of gears, the pitch cylinders or cones which represent the real line of their action must be kept in mind. Two plain cylinders, rolling in contact with each other, could not transmit much power; so, teeth of some kind must be provided. Fig. 1 shows what our grandfathers called "cog wheels." The cogs originally were cast or cut out with a chisel, and roughly smoothed up with a file. These cogs or teeth

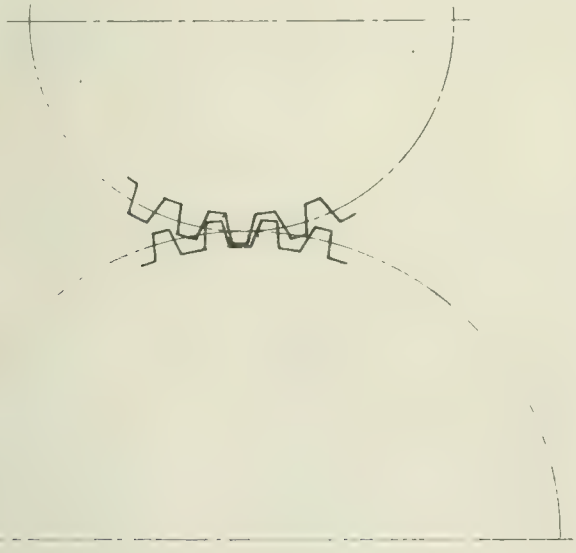

Fig. 1—An Early Form of "Cog Wheels"

prevented slippage and insured a positive ratio of revolutions between two shafts, but there was no uniformity of action. The teeth had no special form; they merely had clearance. These primitive gears succeeded in turning around on time, but they moved intermittently. As

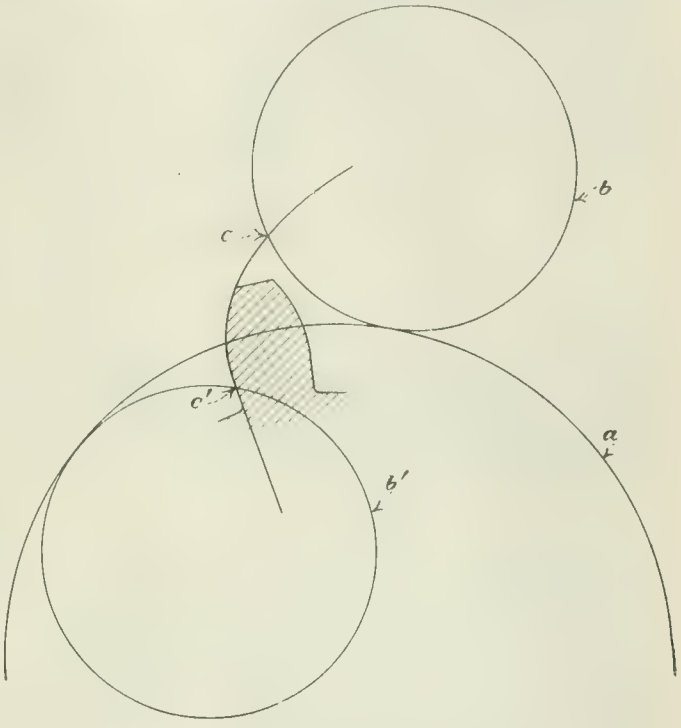

Fig. 2—The Cycloidal Form of Tooth

speeds became higher, it was found necessary to develop a tooth curve that would transmit uniform motion.

Fig. 2 shows the cycloidal form of tooth. The circle *a*, representing the pitch cylinder of the gear, is used as a path on which to roll the smaller circle *b* and the path of the point *c* describes the tooth-form outside of the pitch-circle. The path of the point *c'*, on the inner circle *b'*, describes the curve used for the dedendum of the tooth. A cycloidal rack tooth is shown in Fig. 3. It is the same tooth shown in Fig. 2, except that it has a straight pitch-line. A circle is rolled on one side of the pitch-line to develop the addendum curve, and a similar circle on the opposite side for the dedendum curve. Fig. 4 shows two cycloidal gears meshing together. Between these two gears the imaginary rack line is seen which is the basis of the principle of two gears rolling together. It can be shown that each gear meshes correctly with the rack and, since the rack is symmetrical, the two gears must mesh correctly with each other. The difficulty with this form of gear is that the pressure-angle varies at different points of contact. The point of contact between the gear teeth will come on the imaginary rack line and the direction of pressure will be at right angles to this rack tooth. Since the rack tooth is a curve, the line of pressure at right angles to the rack tooth will fall at various angles. The center pressure between the two gears as they rotate depends upon that angle. The

[1]M. S. A. E.—Sales manager, Lees-Bradner Co., Cleveland.

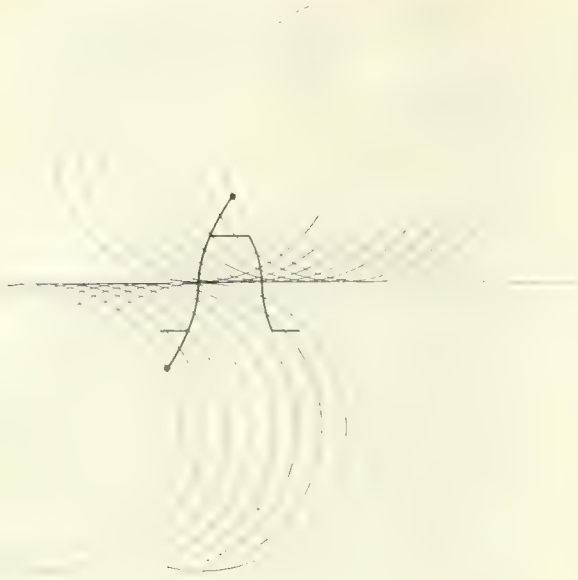

FIG. 3—A CYCLOIDAL RACK TOOTH

pressure angle might vary from 7.5 to 18.0 deg.; consequently, a varying center pressure occurs which causes vibration in the gears and their shafts. This was not satisfactory. The involute tooth was adopted then, so that a constant pressure-angle or straight-sided form of rack tooth might be used.

INVOLUTE GEAR TEETH

Fig. 5 shows the method of laying out an involute tooth. The cord *a* is unwound from the base-circle *b* while a pencil attached to the cord at *c* traces the involute curve. All involute curves unrolled from circles of whatever diameter are exactly the same. The only possible differences are differences in the scale on which the curve is drawn or differences between various parts of the same curve. Taking the circle *d* as the pitch-circle

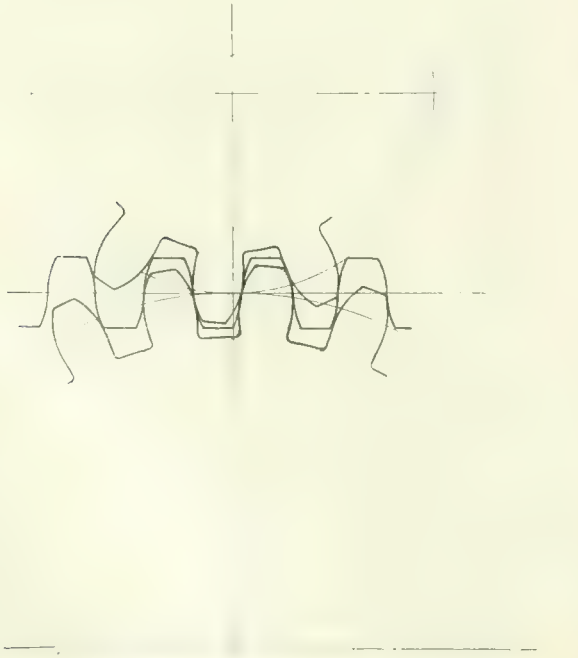

FIG. 4—DIAGRAM SHOWING THE MESHING OF TWO GEARS WITH CYCLOIDAL TEETH

and constructing a tooth, it will be found that it has a pressure-angle of say 20 deg.; going farther out on the curve and constructing another tooth, as at *e*, there would be a much greater pressure-angle, as on the Maag gear; going still further and establishing a pitch-circle at *f*, the pressure-angle becomes so great as to be prohibitive on account of the excessive pressure developed between the centers of the gears. The pressure-angle is dependent upon the ratio between pitch diameter and base-circle diameter. In practice, there must be a means of establishing this ratio so that the involute curve can be

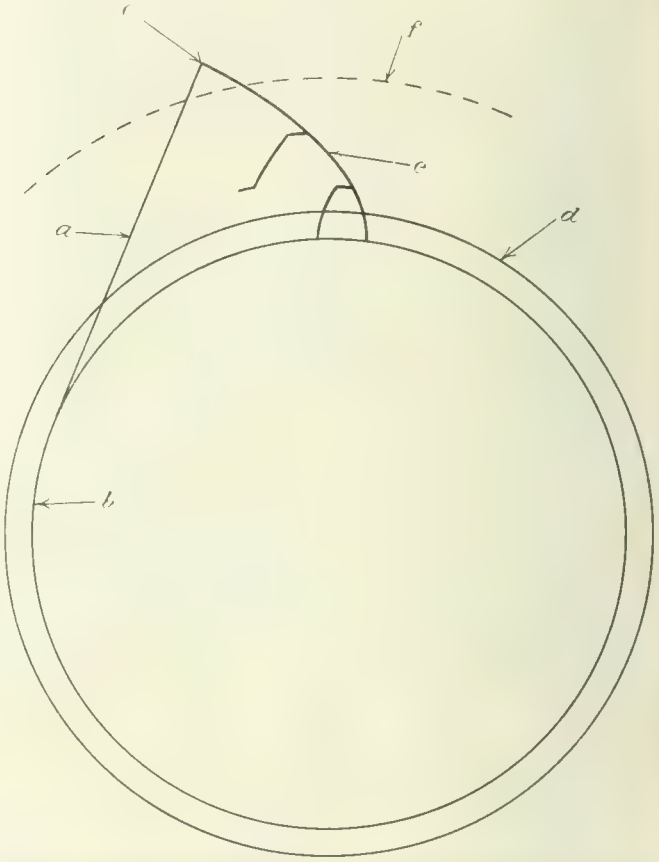

FIG. 5—DIAGRAM ILLUSTRATING THE METHOD OF LAYING OUT AN INVOLUTE TOOTH

drawn on a proper scale to get the desired pressure-angle at whatever pitch diameter is being used. Fig. 6 shows the method of doing this.

Having found the pitch diameter of the required gear and chosen the pressure-angle, with the circle *d* taken as the pitch-circle and 14½ deg. as the pressure-angle, the procedure to establish the base-circle is to draw a tangent at any point, as at *a*, and then draw a line *aa'* making an angle of 14½ deg. at *a*. This line forms a chord to the pitch-circle and is tangent to the required base-circle; so, all that is needed then is to draw a concentric circle *b*, touching the line *aa'* at one point only. If a greater pressure-angle had been chosen, for example, an angle of 20 deg., there would have been a smaller base-circle as shown at the right by *b'*. The base-circle is always smaller than the pitch diameter, although it is usually larger than the bottom diameter of the gear. After having found the base-circle, which is dependent upon the pressure-angle desired, a cord which is wrapped around the base-circle is unwound as was explained for Fig. 5. The path of the pencil at the end of that cord describes the involute curve on a proper scale.

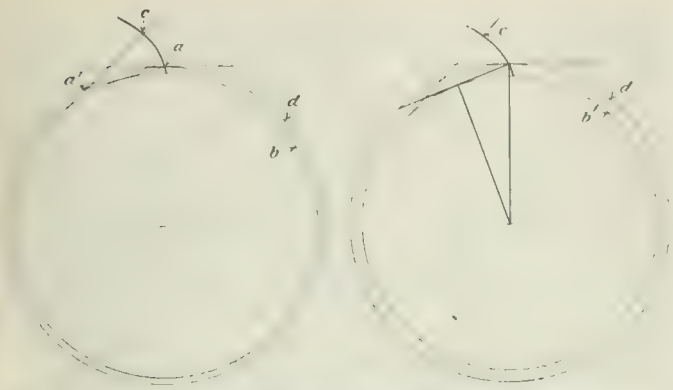

FIG. 6—DIAGRAM SHOWING THE METHOD OF DRAWING THE INVOLUTE CURVE TO GET THE DESIRED PRESSURE-ANGLE

Since the involute curve is designed to mesh with a rack, it should be possible to draw a rack by the same method that is used to draw a tooth on a gear, as in the case of the cycloidal tooth. Fig. 7 shows a straight-sided involute rack drawn in this manner. Starting with the pitch-line *d*, which is in this case a straight line, the rules for laying out an involute curve are followed. The straight line *d* can be considered as an arc having an infinite radius. Selecting a point *a* and drawing a tangent to the arc of infinite radius, it will be found that the tangent coincides with the line *d*. Then the line *aa'* is drawn, which will be found to be of infinite length. It is therefore an infinite distance from the pencil at the end of the cord to the base-circle, and the path of the point *c* will be a straight line at right angles to the line *aa'*, or at 14½ deg. from the perpendicular to the pitch-line. This is working from the involute curve back to the straight-sided tooth of the rack, but the rack is really the starting point, since it is desired to find a tooth curve that would not only give a uniform angular velocity, but a constant pressure-angle. In other words, a curve is desired that will mesh with a straight-sided rack tooth instead of with a curved-rack tooth. In practice, the rack with straight-sided teeth can therefore be taken as a

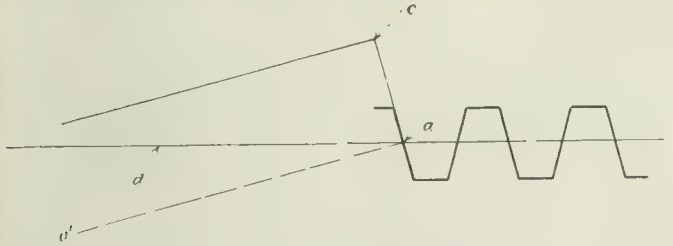

FIG. 7—A STRAIGHT-SIDED INVOLUTE RACK

master form and gear teeth generated by rolling them in mesh with this rack.

Fig. 8 shows a pair of involute gears, each of which has been generated by rolling in mesh with the involute or straight-sided rack. Since the rack is symmetrical, these gears will mesh properly with either side of the rack or with each other. In the consideration of any pair of involute gears, an imaginary rack profile can be visualized as passing between the gears as here shown. Assuming the smaller gear to be the driver and the direction of rotation as shown by the arrow, it will be found that at any point of contact between the teeth the pressure is exerted on a line at right angles to the rack profile. The pressure-angle will always be the same as the angle between one side of the rack tooth and the vertical. A 14½-deg. pressure-angle rack is therefore merely a straight-sided rack with an included angle of 29 deg. Observe the points of contact at *c*, *c'* and *c''*. Lines are drawn to indicate the direction of pressure at each point. It will be noted that these lines all pass through the point of contact between the two pitch-circles.

SPECIFYING GEAR-TOOTH SIZES

Fig. 9 shows the two methods used for specifying tooth sizes. At the left is the system of diametral pitches in common use in this country, and at the right the module system which is used in connection with the metric system. In the first case, the number of teeth is divided by the pitch diameter in inches to get the diametral pitch, while in the second case the pitch diameter in millimeters is divided by the number of teeth to get the module. The rule for transposing from one to the other is to divide either one into 25.4 to get the other. For instance, a gear of 2 module would be of 12.7

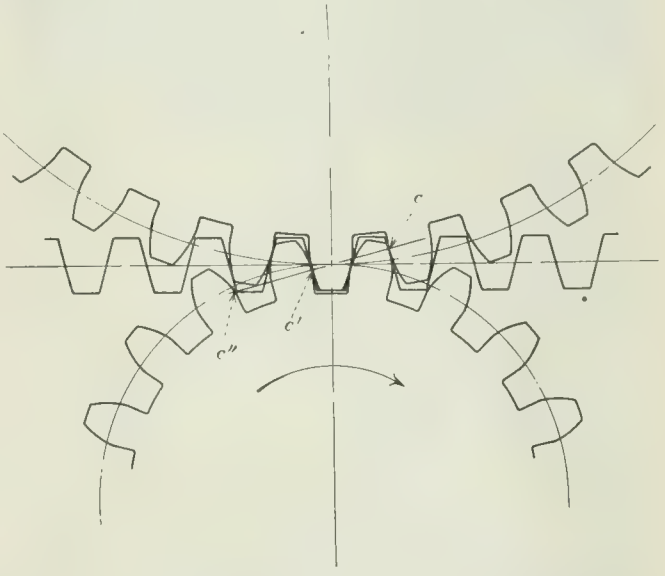

FIG. 8—A PAIR OF INVOLUTE GEARS, EACH OF WHICH HAS BEEN GENERATED BY MESHING WITH AN INVOLUTE OR STRAIGHT-SIDED RACK

diametral pitch, a 10-pitch gear would be of 2.54 module, and so on. To remember what diametral pitch is measure off 3.1416 in. on the pitch-line and count the teeth, which will be the diametral pitch. A gear of 1-in. pitch diameter has as many teeth as its diametral pitch. In the old-style single-cutter type of gear-cutter it was necessary to lay out a series of involute tooth-forms and make a series of cutters for each pitch. The tooth-forms generated by the same rack on two gears of different diameters will be different. It was customary to approximate

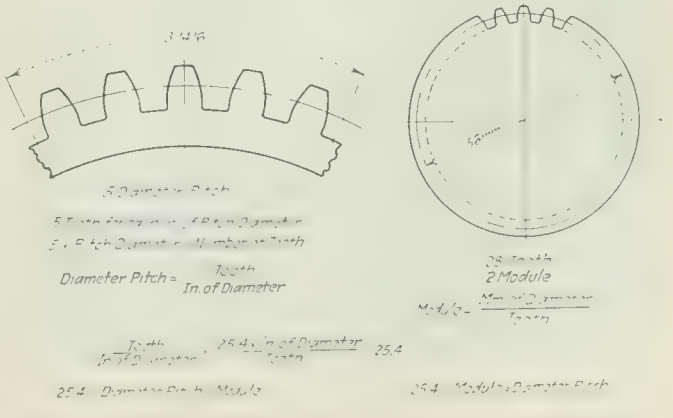

FIG. 9—THE TWO METHODS USED FOR SPECIFYING TOOTH SIZES

these tooth-forms by the use of eight different cutters, except in cases where it was thought worth while to go to the expense of buying a special cutter for the exact number of teeth to be cut. These old-style cutters were variously known as "disc cutters," "single cutters" and "involute cutters." While these cutters were based on the involute system, they were not true involute forms because some allowances had to be made to make them cover a range of gear diameters. This system was devised by Brown & Sharpe; so, it also is called "the B & S tooth-form."

Referring again to Fig. 8, this shows the basis of the various generating methods of producing involute gears. The most primitive form was merely a planing, shaping or slotting machine, using a single planing tool. This was fed in to the desired depth and was then backed out; the gear blank then was indexed a small part of a tooth, the tool was moved a corresponding distance tangential to the work and was again fed in to depth. The tool in this case represented one tooth of the rack. The next step of progress was to use such a tool or a grinding wheel to generate a cutter in the form of a gear, and then to use this cutter as a planing tool to generate another gear. In Fig. 8, the pinion might be considered to be such a cutter and the larger gear to be the blank, each moving slightly about its own axis between cuts. It was necessary in this case also to make some deviation from the true involute, but for a different reason. The gear-shaped planing-tool, or gear-shaper cutter, will not completely generate the rack from which it was generated, so the tooth-form is modified slightly in order that it will cut gears which roll together properly.

Another form of planing tool used to generate involute gears is made by using the rack itself for a tool. The machine employed resembles a slotting machine, save that a relative motion is imparted to the cutter and the work to secure the generating effect. A machine of this type is used to produce the Maag gear which, being an involute tooth-form with a greater pressure-angle than ordinarily used, calls for a rack having a larger included angle between the teeth. Both of the last-mentioned methods employ machines operating like a slotting machine and rotating the work during the process, but in the first case the gear-shaped tool rotates in conjunction with the work rotation, while in the latter case the rack-shaped tool moves along tangentially in conjunction with the work rotation. The former is a simpler movement to provide for, but the latter machine affords a more complete generation of the involute tooth on the gear and is more direct in that the rack-shaped tool is used directly to generate the gear instead of being used to generate the cutter which produces the gear. It was right along this line of thought that the idea of hobbing spur and helical gears was first conceived.

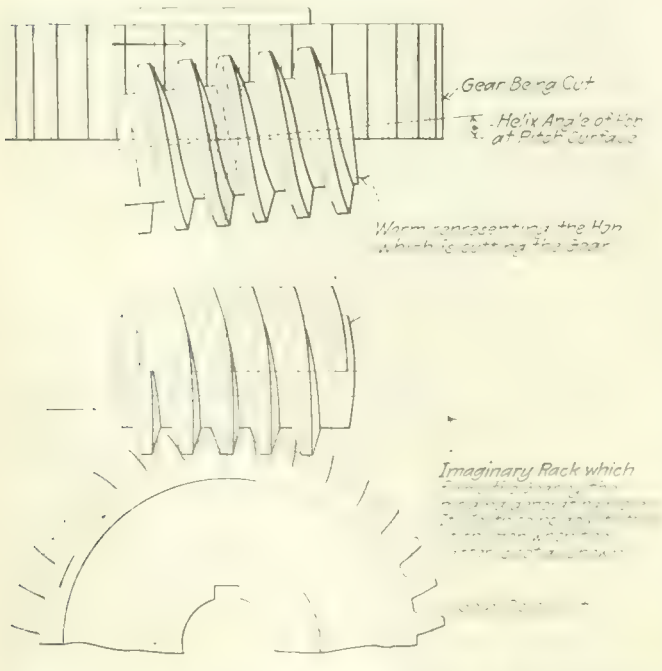
Gear Being Cut
Helix Angle of Hob at Pitch Surface
Worm representing the Hob which is cutting the Gear
Imaginary Rack which

Fig. 10 Diagram Illustration to Illustrate the Hobbing Principle for Spur and Helical Gears

Gear Hobs and Gear-Hobbing

Fig. 10 shows the principle of generating involute teeth from the rack section of a hob. The rotation of the hob provides in effect the tangential movement of the rack as indicated by dotted lines. This method is accomplished with the simpler rotary motion because that affords the more complete generation, and the gear is generated directly from the rack instead of through the medium of an intermediate generation. In addition to this, the hobbing method has the advantage of speed, since it is a continuous cut from start to finish of an arbor full of gears, as compared with reciprocating motion on any other type of gear-cutter. To bring this point out clearly, a partly finished gear is shown in Fig. 11. After going over the principles of hobbing in what seems to be a thorough manner I am sometimes asked how, after having cut through one tooth, the blank is indexed for the next tooth. It is evident from Fig. 11 that, after one tooth has been cut through, it is not necessary to index; the entire gear is finished at one traverse past the hob. The blanks rotate constantly during the process, in the same manner as in hobbing a wormwheel, but the feed is along the axis of the blanks instead of being in toward the center of the blank. The invention of the process was inspired by the older method of hobbing a wormwheel. In Fig. 10 it can be assumed that the lower view illustrates the hobbing of a wormwheel instead of a spur gear. The next step is to tilt the hob axis, as shown in the upper view, so that the teeth will be cut straight across the face of the blank instead of at an angle. Then, after the hob is fed in to the proper depth, it is caused to travel across the face of the blank while the hob and the blank continue to rotate at their proper ratio.

When "feed" is spoken of in connection with hobbing a spur or helical gear, travel along the axis of the blank during one rotation of the blank is meant. This feed can be obtained by traveling the hob or by traveling the blank. We prefer the latter, as hobbing is essentially a milling operation and in milling practice it has been found best to travel the work rather than the cutter.

Fig. 12 shows a Lees-Bradner built-up hob, in which separate racks are assembled after having been ground all over. In this hob it is easier to visualize the rack profile than in a solid hob such as is shown in Fig. 11. Solid hobs are formed on backing-off machines, giving the same relief at the bottom between teeth as at the top of teeth. Some solid hobs are ground on the sides of the teeth in backing-off machines after hardening. This eliminates the distortion of teeth in hardening and insures an accurate rack profile from which to generate the gear. Our method in making this built-up hob is to do the grinding on the sides of the teeth after hardening, but before assembling the racks in the hob body. The

advantage is that we can grind with a larger wheel and hold to closer limits. The disadvantage is that we cannot make these hobs in small diameters. In most cases where extreme accuracy is not required, we recommend the use of smaller solid hobs, even though we do not make them, for the smaller-diameter hobs give a higher production. These built-up hobs are used almost exclusively on timing-gear work, where the quietest possible gears are much to be desired.

Fig. 13 shows one of our machines cutting flywheel gears with a solid hob. On this work production is of greater importance than extreme quietness of opera-

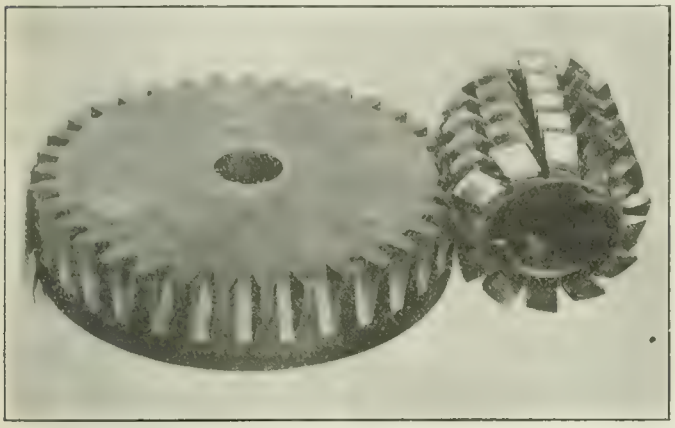

FIG. 11—RELATIVE POSITIONS OF THE HOB AND A PARTIALLY FINISHED GEAR BLANK

tion; so we recommend a solid hob with multiple threads. There are about 130 teeth on this gear and the face is about 1 in. The production is 120 flywheel gears in 9 hr., which would not be possible with a single-threaded hob. The reason for the higher production of the multiple-threaded hob and the hob which is smaller in diameter is that they call for a higher speed of work rotation with the same cutter speed, measured in feet per minute. The ratio between the hob and the work rotation speeds is inversely as the ratio between the number of threads on the hob and the number of teeth in the gear that is being cut. Revolving the work at a higher speed allows cutting across more gear-face in a minute without using an excessive feed per revolution of the blank. We do not in any event recommend the use of multiple-threaded hobs for timing-gear production. Some makers are using multiple-threaded hobs for a roughing cut on timing-gears, but we believe in taking one cut only and being particular to take that one cut right. The amount of metal removed from a timing-gear does not call for two cuts if the machine is rigidly constructed.

Regarding the amount of metal removed, another important point affects the running qualities of gears. When metal is removed from one side of the gear first, cutting some teeth entirely through before others are touched, there is a distortion of the blank. In the hobbing process metal is removed uniformly from all sides of the blank. This is important in view of the expansion of the blank from the heat of the cut. When the first tooth is cut in a cold blank and the last tooth cut in a heated blank, there is a difference in the depth of the teeth. Metal will distort under stress or heat and on an operation so important as gear-cutting these facts should be borne in mind. It is frequently thought, for instance, that a transmission gear is too heavy to distort and will support itself on the arbor during the cut.

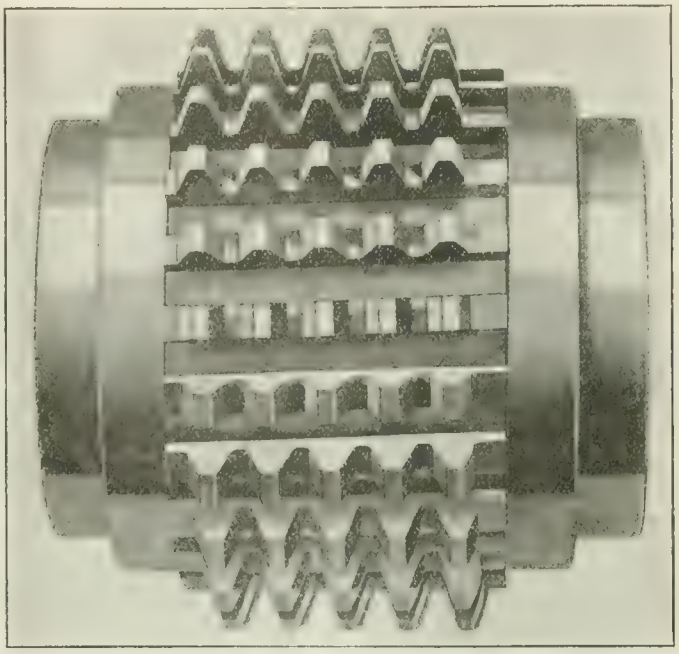

FIG. 12—A BUILT-UP HOB IN WHICH SEPARATE RACKS ARE ASSEMBLED AFTER BEING GROUND ON ALL SURFACES

This may have been all right on the old-style gear-cutting machine with its single cutter at work on one tooth, because the blanks were probably as rigid as the overhanging arm which supported the work arbor and it would have seemed to be out of reason to support them with plates, but it is much different in hobbing. The hob is working on several teeth at a time and removing two or three times as much metal; methods that were satisfactory on the old-style gear-cutting machine will not give the hob a chance to do its best work.

While tractor transmission gears appear heavy enough to support themselves when being machined, plates are necessary to clamp them on the work arbor. The same thing was true of the flywheel-gear job shown in Fig. 13. When the gears have been finished, the hob is backed out of engagement with the gear teeth, preparatory to removing the finished gears from the machine. This is the

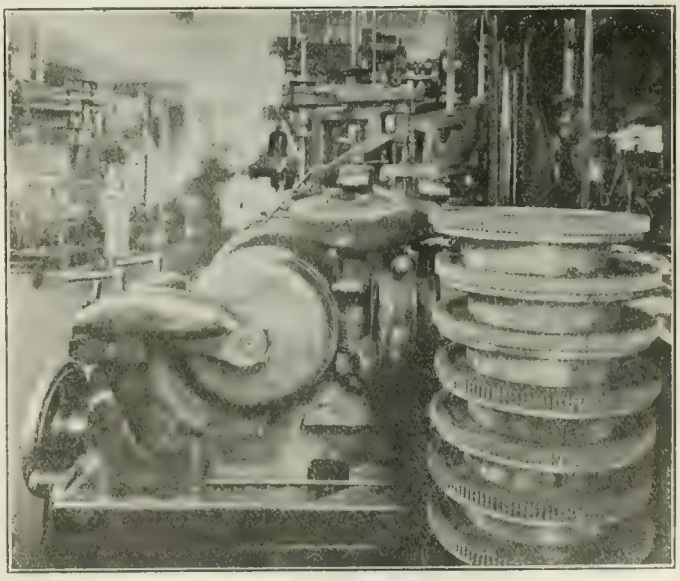

FIG. 13—FLYWHEEL GEARS BEING CUT BY A SOLID HOB AT THE RATE OF 120 GEARS IN 9 HR.

proper method of procedure, but it was not possible on the old-style machine. A modern gear-cutting machine is provided with a micrometer stop on the handwheel at the front, so that the hob is automatically stopped at the proper depth for the next arbor full of gears.

Helical and Worm Gears

Referring again to the subject of tooth-forms and the constant search for more smoothly running gears, we find no basic change of tooth-form since the introduction of the involute tooth. We have, however, made an advance through the introduction of helical gears. In the pair of gears shown in Fig. 8 there are two teeth in working contact at the points c and c'. When two teeth engage they make a line contact across the entire working face of the gear. If this pair of gears could be produced with absolutely perfect tooth curves, there still would be a slight shock at the time of contact between any two teeth because those already in action are deflected slightly by the load they carry. It would therefore be an obvious advantage to have more teeth in mesh at one time, or to have them come into engagement gradually, so as to decrease the vibration and consequently reduce gear noise to a point that is unattainable on a commercial basis when straight spur gears are used.

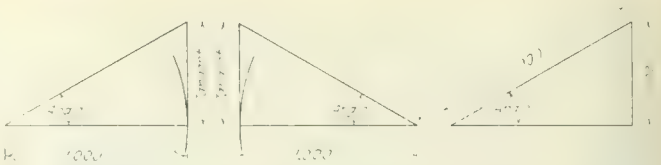

Fig. 16—Right-Angle Triangles Used To Enable the Student To Identify the Relations between the Angle opposite the Right Angle and Its Tangent and Sine

There is, however, no difference between these two types so far as the cutting of the gears is concerned. Gears running on parallel shafts roll together with a slight sliding action like that of spur gears, and helical gears running on shafts at right angles slide together with a slight rolling action similar to that of a worm gear.

Helical gears and worms are easily confused, as is shown in Fig. 14. A pair of helical gears designed to operate on shafts at right angles to each other is shown at the left. If a standard involute rack of the proper pitch were engaged with first one and then the other of these gears, it would be found that the rack must lie along the line indicated at right angles to the teeth. Any method of generation to produce these gears would be based on a rack with its profile in a plane at right angles

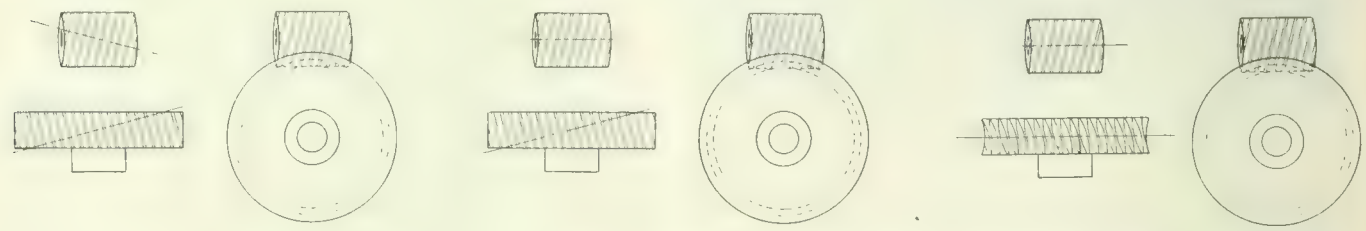

Fig. 14—The Use of Helical and Worm Gears on Shafts at Right Angles to Each Other
The View at the Left Illustrates the Correct Relative Positions of a Pair of Helical Gears; in the Central View the Smaller Gear Is Cut as a Worm with a Rack Profile along Its Axis Instead of at Right Angles to the Teeth; the Solution of This Problem Is the Use of a Worm and Wormwheel as Shown at the Right

The solution of this problem is to cut the teeth in helical form instead of parallel to the axis of the gear. This is the reason for the universal adoption of helical timing-gears in place of spur gears. Helical gears are ordinarily thought of as being in the two classes of those which operate on parallel shafts and those which operate on shafts at some other angle, usually at a right angle.

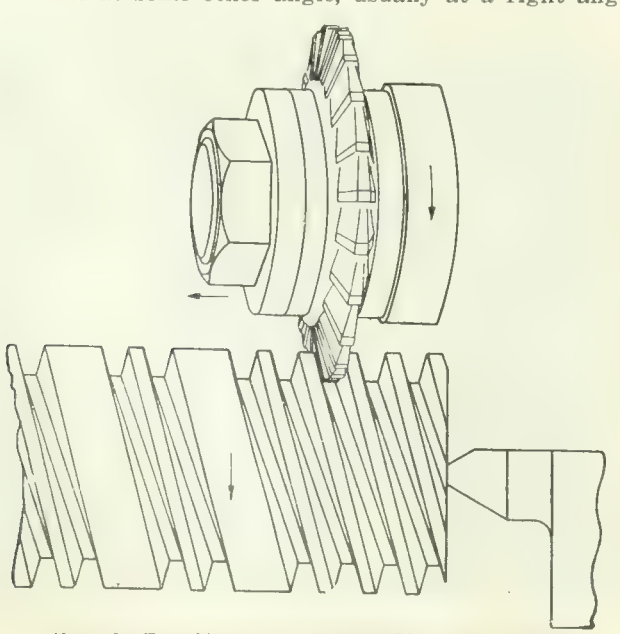

Fig. 15—The Method of Thread-Milling a Worm

to the tooth under consideration. If we were to lay out the involute curve, we would work from a base-circle in this plane; that is, normal to the tooth. When these two gears are meshed together, these two lines coincide. It can be said that the base-circles fall in the same plane or that the direction of rack movement is the same. Taking an imaginary rack profile and allowing it to pass through between the two gears, as was done in Fig. 8, it will be found that the direction of rack movement is normal to the teeth; that is, at right angles to them.

What appears to be the same pair of gears is illustrated in the central portion of Fig. 14, but in this case the smaller gear is cut as a worm; that is, it has a rack profile along its axis instead of at right angles to the teeth. It is obvious that when this pair is meshed together the base-circles will not fall in the same plane. A worm of the proportion shown can be thread-milled in less time than a helical gear of the same specifications can be hobbed. The solution of this problem is to use the worm in conjunction with a wormwheel as shown at the right of Fig. 14. This is a worm and wormwheel such as might be used in a steering-gear. The worm is thread-milled with a straight-sided cutter, giving it practically a rack profile along its own axis, and the wormwheel is hobbed with a hob similar in form to the worm, although preferably it is slightly larger in diameter. The longitudinal section of the hob represents the rack which generates the wormwheel. When this worm and wormwheel are meshed together, the directions of rack movement coincide. In addition to effecting a saving of time in the production of the worm, a wormwheel of these

proportions can be hobbed in less time than it can be hobbed as a helical gear.

Another fact regarding worm gears is often misunderstood. Assuming that the wormwheel shown at the right of Fig. 14 has 36 teeth and that the axial pitch of the worm is ⅓ in., this means that the pitch circumference of the wormwheel is 36 times ⅓ in., or 12 in. The pitch diameter of a gear is that diameter at which the circular motion of the gear equals the tangential movement of the imaginary rack from which it is generated. Cutting this wormwheel oversize or feeding the hob in deeper will not change the pitch diameter, but it will change the form of tooth. This same rule applies to spur and helical gears.

Fig. 15 illustrates the method of thread-milling a worm. The job shown might be a triple-threaded worm or a triple-threaded lead-screw with an Acme thread. The calculations involved are practically the same as those required to figure out gears on a lathe. The cutter is traveled along the axis of the work a distance of one lead for each rotation of the work. The difference is that in this case a milling cutter is used instead of a lathe tool. The axis of the milling cutter is inclined so that it falls at right angles to the thread that is being cut, and the work rotation is at a suitable peripheral speed for a milling feed. In addition to the substitution of a milling cutter and the corresponding change in the speed of work rotation, one theoretical point must be considered. A lathe tool with its cutting profile in a plane passing through the axis of the work will reproduce itself in the thread. In other words, if the lathe tool is ground to an angle of 29 deg. and it is set straight, it will produce a thread with a 14½-deg. pressure-angle on each side. The teeth of the thread-milling cutter are, however, operating in a plane normal to the threads; so, there is a difference between the axial pressure-angle of the thread and the angle of the cutter or normal pressure-angle of the thread. In cutting worms of steep angles such as are used in motor-truck axles, the difference between the normal and the axial pressure-angles becomes clear and it is necessary to make the required correction in angle of the cutter, for worms are commonly specified by the axial pressure-angle. We usually know what linear or axial pressure-angle is desired and it is necessary to specify a cutter to produce it. We have evolved a formula for making this correction; reduced to its simplest form, it is as follows:

> The tangent of the Axial Pressure-Angle times the cosine of the Thread-Angle equals the tangent of the Normal Pressure-Angle

I will not attempt to explain how this formula is derived, for it is a long process. It is possible to reduce most of the calculations on worms and helical gears to a simple form which requires the solution of only one triangle. In this connection I will present my method of teaching the shop man in one lesson enough of the science of trigonometry so that he will be equipped to make worm and helical gear calculations.

Helical and Worm-Gear Calculations

Fig. 16 shows at the left a plain right-angle triangle. Taking the base-line as a radius and striking an arc, it is an easy matter to identify the side of the triangle which is naturally called the tangent. The base-line we will call 1.000. I merely tell the student that the base-line is 1.000 and that the tangent for any given angle is found in the book. If he remembers this and has mathematical ability enough to multiply and divide, he will appreciate the fact that with a base-line of 2 he can find the perpendicular or tangent side of the triangle by multiplying the tangent he finds in the book by 2. He also should appreciate the obvious fact that quantities multiplied together can be divided again; so, in case he happens to know the perpendicular side of the triangle and does not know the length of the base-line, he can divide the perpendicular by the tangent of the angle and find the base-line. It equally is obvious that, knowing both the perpendicular and the base-line, it is possible to find the tangent by dividing the perpendicular by the base-line and, having found the tangent, he can look in the book and find out what the angle is. The next step in this lesson is to turn the triangle over and look at it from the other side, as in the middle view, calling the student's attention to the fact that it can be turned up-side down or sidewise to fit his problem.

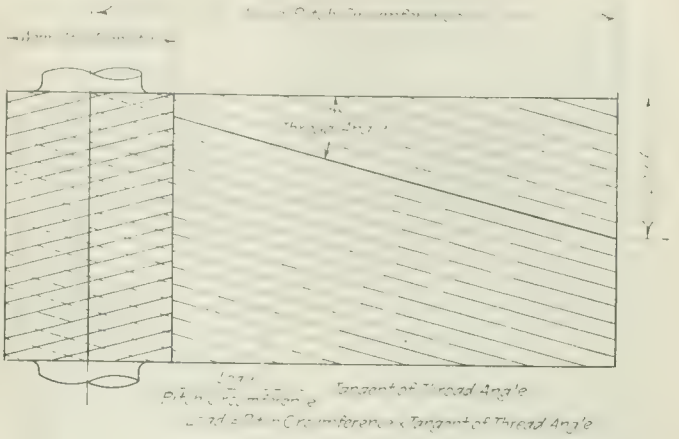

Fig. 17—An Application of the Right-Angle Triangles Shown in Fig. 16 to the Solution of a Worm

Another right-angle triangle is shown at the right of Fig. 16 to illustrate the sine. To impress this on the student's mind I point out that the hypothenuse is called 1.000 in this case and that the sine and the tangent approach the same value when the angle is very small. If the angle were only 1 deg., it would not make much difference whether he used the base-line or the hypothenuse as a stick to measure the perpendicular. It is easy to remember what the word "tangent" means and then all he has to do is to remember that the sine is measured the

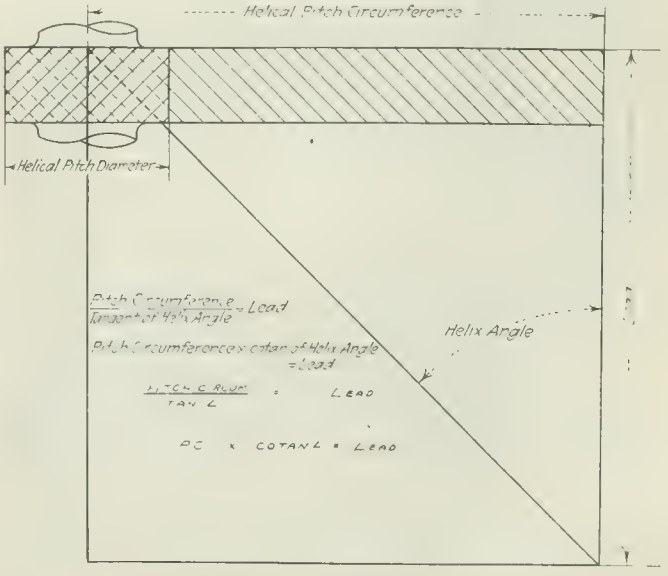

Fig. 18—Corresponding Diagram for a Helical Gear

other way, and that the figure he finds in the book for the sine of any angle tells how much the perpendicular is as compared to an hypothenuse of 1.000. Having learned what the sine and the tangent are, it is necessary only to learn that the prefix "co" means "corresponding"; in other words, that the cotangent is the tangent of the angle in the opposite corner, and likewise the cosine is the sine of the angle in the opposite corner and that these angles added together will always make 90 deg.

Fig. 17 shows how this elementary course in trigonometry is applied to the solution of a worm. Let us assume that we have taken a worm and turned it down until we come to its pitch diameter. If we were to roll this worm over an ink-pad and then over a piece of paper, we would get the development of the worm. We show here that the worm has been rolled just far enough to make one revolution, so that the length of the impression on the paper is the pitch circumference of the worm. Each tooth makes a straight line and the angle between this tooth and the top edge of Fig. 17 is the thread angle of the worm. We know the pitch circumference of the worm and we know the lead of the worm; so, we are able to construct a right-angle triangle with two known sides. Taking the triangle in the center of Fig. 16 and turning it upside down, we find that it fits into our diagram; so, we know that dividing the lead by the pitch circumference will give us the tangent of the thread angle, or, if we happen to know the pitch circumference and angle, we could find the lead by multiplying the pitch circumference by the tangent of the angle.

Fig. 18 is a very similar diagram made with a helical gear. So far as the calculation of lead, diameter, angle and the like is concerned, a helical gear is the same thing as a worm except that we make a practice of speaking of the "tooth angle" or "helix angle" in a helical gear, meaning the angle between the tooth and the axis of the gear; whereas, we speak of the "thread angle" in a worm, meaning the angle between the thread and a line perpendicular to the axis. Having rolled the gear out on a flat surface, in the same manner that we did the worm, and

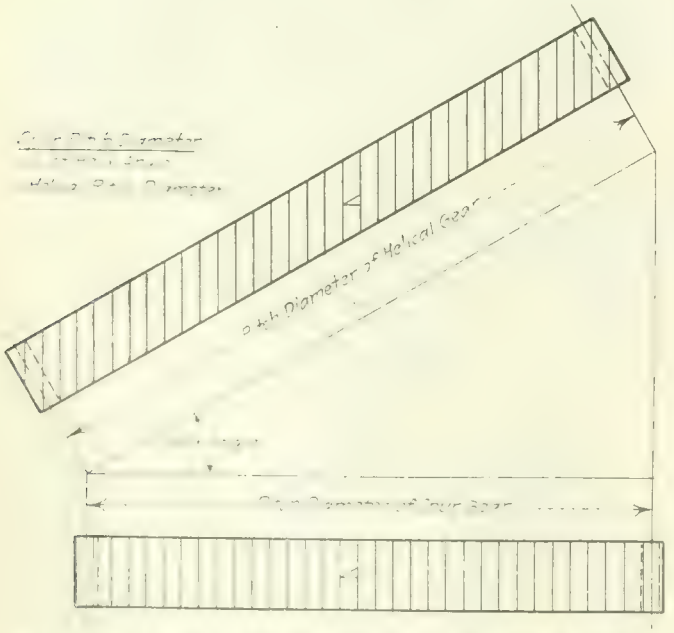

FIG. 19—THE MOST COMMON CALCULATION IN WORKING WITH HELICAL GEARS

By the Use of This Diagram in Conjunction with the Triangles of Fig. 16 It Is Possible To Find the Pitch Diameter of a Helical Gear Knowing the Helix Angle, or To Find the Helix Angle Knowing What the Diameter of the Gear Should Be.

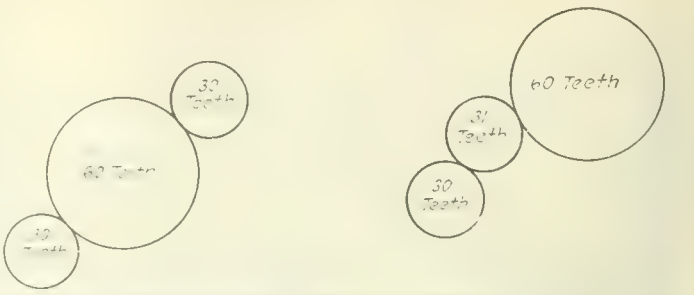

FIG. 20—DIAGRAM SHOWING HOW IT IS POSSIBLE TO MAINTAIN THE SAME RATIO IN A GEAR TRAIN BY CHANGING THE HELIX ANGLE TO MAKE UP FOR A VARIATION IN THE NUMBER OF TEETH

	Cosine of Angle, Deg.	Min.		Cosine of Angle. Deg.	Min.
29/30 = 0.96667	14	50	7/8 = 0.8750	28	57
28/30 = 0.93333	21	2	8/9 = 0.8889	27	16
27/30 = 0.90000	25	50	8/10 = 0.8000	36	52
26/30 = 0.86666	29	56	9/10 = 0.9000	25	51
25/30 = 0.83333	33	33	10/12 = 0.8333	33	33

forming a right-angle triangle, we find that we know the pitch circumference and the helix angle and we want to find the lead. The triangle at the left of Fig. 16, tilted up on its left side so that the tangent becomes pitch circumference and 1.000 becomes lead, serves the purpose this time, and it is shown that the pitch circumference divided by the tangent of the angle equals the lead. Should we happen to know the lead and not the angle, we can find the tangent of the angle by dividing the lead into the pitch circumference.

Fig. 19 shows what is probably the most common calculation in working with helical gears; that is, to find the pitch diameter of a helical gear knowing the helix angle, or to find the helix angle, knowing what diameter the gear must be. We have here a right-angle triangle of which the base-line is the pitch diameter of a spur gear and the hypothenuse is the pitch diameter of a helical gear with the same number of teeth and the same pitch. If the teeth of one gear are traced across the diagram, it will be found that they coincide with the teeth of the other gear. If a small triangle is drawn in between two teeth of either gear, a triangle exactly similar to the larger triangle will be formed.

Let us take the triangle shown at the right of Fig. 16, just as it stands, and lay it on this triangle. We are not interested in the side that is marked "sine," but we are interested in the base-line, which is the sine of the angle in the opposite corner. It is therefore the cosine of the helix angle; and we know that the diameter of the spur gear is to the diameter of the helical gear as the cosine is to 1.000. In other words, to convert the pitch diameter of a spur gear into the pitch diameter of an equivalent helical gear, we merely divide the pitch diameter by the cosine of the helix angle.

Fig. 20 shows this formula applied to a problem which many automobile engineers had to solve a few years ago when the change was made from spur to helical timing-gears. Since the problem of arriving at a suitable number of teeth, pitch and tooth angle, is handled practically the same way today, we may find this old problem interesting. At the left is a layout of three gears with 30, 60 and 30 teeth respectively. Should we change this to 29, 58 and 29 teeth we would keep our ratios and reduce the pitch diameter of each gear by the ratio of 30 to 29, but if we give the teeth of each gear a certain amount of helix angle we can make up the difference. Therefore, we divide the smaller quantity, 29, by the larger quantity, 30, and find that the cosine of the required angle is 0.96667 or an angle of about 14 deg. 50 min. In the same manner we can reduce the number of teeth to 28

and 56, going as far as we like, one tooth at a time on the 30-tooth gear and two teeth at a time on the 60-tooth gear, obtaining the helix angles shown at the left of Fig. 20. At the right side of Fig. 20 we find another gear layout which involves a 31-tooth gear; unhappily, this is a prime number and prevents our making a change in the numbers of teeth but, as an alternative, we can change the pitch. Assuming that these are 7-pitch gears, we might keep the same number of teeth in each gear and change them to 8-pitch gears. This would reduce the pitch diameter of each gear by the ratio of 8 to 7. Following the same process of dividing the smaller quantity by the larger quantity, we find that a change from a 7 to an 8-pitch gear gives us a cosine of 0.8750 or an angle of 28 deg. 57 min. If we started with 8-pitch and changed to 9-pitch gears, we would get a cosine of 0.8889 or an angle of 27 deg. 16 min.; likewise a change from 9 to 10-pitch gears would give us a cosine of 0.9000 or an angle of 25 deg. 51 min.

Some of the helix angles shown are still in use on popular cars. It is only natural that, having once established these odd angles to accomplish the desired change to helical gears without disturbing gear-centers and discarding a lot of blanks, these angles were adhered to in many cases and have even been copied on new designs.

Hobbing Helical and Worm Gears

Fig. 21 shows the process of hobbing a right-hand helical gear. Note that the direction of the cut on this gear is not along the axis of the gear, but at a considerable angle to the axis. This emphasizes the importance of supporting the work arbor rigidly at both ends instead of at one end only. It will be observed that the designer has paid considerable attention to rigidity in the construction of this machine. Fig. 22 is a diagram of the problem of setting up a gear-hobbing machine to generate a given helix angle. The first step in making this calculation is to determine the lead of the gear as explained in connection with Fig. 18. Let us assume the lead in this case to be 10 in., the feed per revolution of the blanks to be 0.050 in. and the number of teeth to be 50, using a right-hand single-thread hob to cut a right-hand helix. Having 50 teeth in the gear and 1 thread in the hob, we must gear up so that the hob makes 50 revolutions for 1 revolution of the blank. Each hobbing machine has a particular constant between the hob and the work spindles. In this case the constant is 32 or, in other words, when the change-gear train has a ratio of 1 to 1, the machine will be set up to cut 32 teeth. To

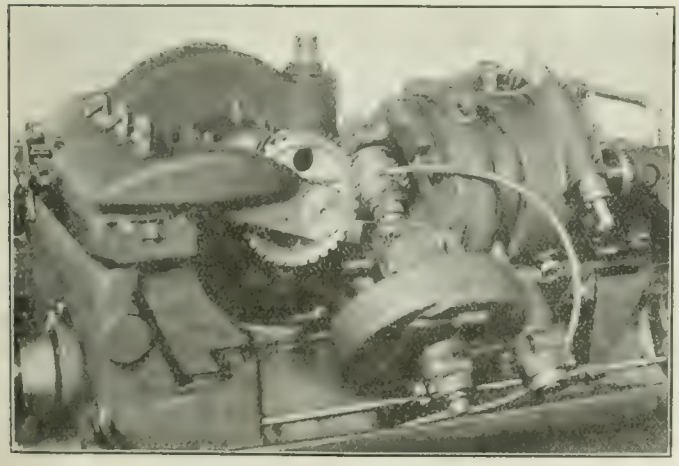

Fig. 21—Hobbing a Right-Hand Helical Gear

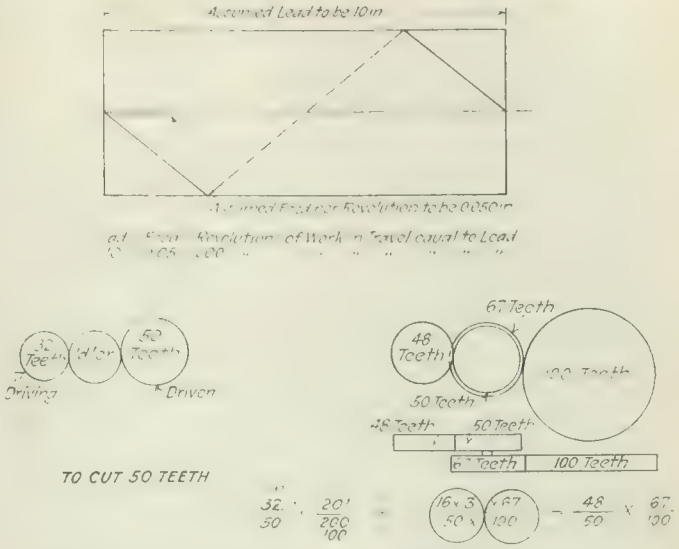

Fig. 22—Diagram Showing How a Gear-Hobbing Machine Should Be Set Up To Generate a Given Helix Angle

cut 50 teeth, we must therefore use a 32-tooth gear driving a 50-tooth gear, or some other combination producing the same ratio.

Having selected a feed of 0.050 in. per revolution of the blank, we find that in cutting a gear face of 10 in. the gear blanks will have made 200 revolutions. We arrive at this by dividing the lead of 10 in. by the feed of 0.050 in. This is the result we would have if they were spur gears, but it happens that we want to cut helical gears and we must therefore introduce an extra revolution. This extra revolution amounts to the same thing as setting up a universal milling-machine so that the work rotates one turn while the cutter travels the length of the lead desired. The machine is making 200 revolutions normally but to generate this helix we must make 201 revolutions; therefore, we multiply the gear ratio by the quantity 201/200. This gives us the combination:

$$(32/50) \times (201/200)$$

which equals

$$(16 \times 3 \times 7) \div (50 \times 100)$$

Reducing this to workable gear-sizes we have:

$$(48/50) \times (67/100)$$

The diagram in Fig. 22 shows how this gear combination would be put together, using a compound in place of the idler. If we find after setting up the machine that we want the work to rotate in the opposite direction, we merely put in one more idler gear or take one out, according to which is more convenient.

In obtaining exact results there is a correction to be made in the feed, for we are now making 201 revolutions of the work in the cycle and our assumed feed of 0.05 in. per revolution of the work would give us a lead of 10.05 instead of 10.00 in. The corrected feed is found by dividing the new number of revolutions, 201, into the desired lead of 10.00000 in., which gives us 0.04975 in. To allow for making such corrections as this, our machine is designed with a change-gear mechanism which permits an almost infinite number of feed-gear combinations. Without such a feed mechanism it is necessary to let the error pass or to use a special change-gear with a large prime number of teeth in the rotation gear train. Stated as a formula, the problem of gearing-up to generate a helical gear on any hobbing machine is:

$$G/G_1 = (C \times L/F) \div (N[(L/F) \pm 1])$$

where

C = Number of revolutions made by the hob for 1 rev-

olution of the work when change-gears having a ratio of unity are put in the work rotation train
F = Feed
G = Product of the driving gears
g_1 = Product of the driven gears
L = Lead
N = Number of teeth to be cut

The sign $\pm$ is read "plus" when the gear is of the *opposite* hand from the hob; it is read "minus" when the gear is of the *same* hand as the hob.

Fig. 23 shows the modern process of hobbing a wormwheel. The relation of the hob and the wormwheel is practically the same as on the oldest type of hobbing machine and, in fact, the roughing of this wormwheel is accomplished in the same way; that is, by feeding the work toward the hob while both are driven at the proper ratio to each other. In this case, however, we stop the in-feed before we reach the finished depth of tooth and then start the hob to feeding longitudinally upon its own axis, introducing a differential rotation of the work to compensate for this tangential feed. The result is that each tooth of the hob is moved along its axis to a great number of successive positions, accomplishing the effect of a hob with an infinite number of teeth. This is the latest method of producing worm gears such as are used in truck axles. The importance of this longitudinal feed is increased by an increase in the thread-angle of the worm for, the steeper the thread-angle of the hob is, the fewer teeth there are in any one thread. This is a comparatively new machine which we have developed for this particular class of work, to allow the designer to employ the steeper thread-angles which are more efficient and accommodate themselves more readily to the gear-ratios desired.

Ring-Type Thread-Milling

Fig. 24 shows an operation which is sometimes called hobbing, but we prefer to call it ring-type thread-milling; together with the machine upon which it is done. Th ring-type cutter is not strictly a hob because it has no lead and is merely a gang of single cutters made in one piece. The operation shown is milling an ordinary V-thread on an axle shaft, transmission shaft, steering-knuckle or some such part. The axis of the cutter is set parallel to the axis of the work and is rotated at a suitable milling speed independent of the rotation of the work. The cutter is, however, given a longitudinal movement upon its own axis, parallel to that of the work, at a rate equal to one lead of the thread while the work makes one revolution. With the cutter in motion, the first operation is to engage the feed, which starts the work rotating and the cutter traveling parallel to the axis of the work. The operator then brings the cutter in to its full depth, cutting a complete thread across the full face of the part to be threaded. After the work has made slightly more than one complete rotation to insure that the thread is finished all the way around, the cutter is backed out and we have a complete thread. This method of cutting complete threads at one rotation of the work is similar to the so-called "hobbing" of tap and die chasers. It produces a very accurate thread and the beauty of it is that all of the threads are alike.

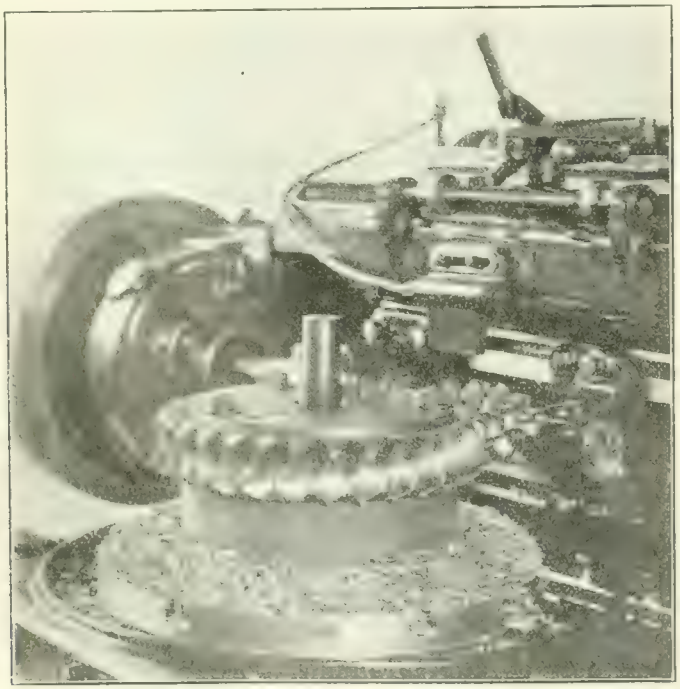

Fig. 23—Hobbing a Wormwheel

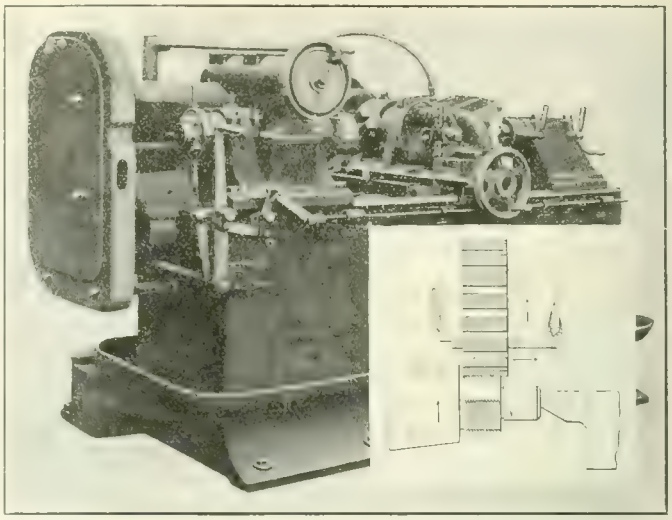

Fig. 24—Milling an Ordinary V-Thread on a Shaft by the Use of a Ring-Type Cutter

This process of producing threads has gained much in popularity as a result of the war. Many manufacturers who contracted to deliver large numbers of shells and then found that the Government specifications for thread limits could not be met by ordinary methods, owe their salvation to the thread milling-machine. During this period our company devoted its entire capacity to the production of these machines for war work, covering chiefly the production of shells, aircraft-engine parts and even plug and ring thread-gages.

THE DISCUSSION

W. C. Keys:—Is the Lees-Bradner gear-hobbing machine readily suitable for hobbing and milling threads, and can it mill internal threads?

Glenn Muffly:—We sometimes mill threads on our gear-hobbing machines, but our gear-hobbing and thread-milling machines are distinct types. It is possible to mill an internal thread by the method shown in Fig. 24, although for internal work we build collet-type machines, holding the work in collet chucks, either air or hand operated, or in a special fixture of some sort. The cutter spindles on these machines are not required to swivel, because internal threads are cut only with ring-type cutters.

M. R. WELLS:—What is your method of determining the shape of the milling cutter?

MR. MUFFLY:—The ring-type thread-milling cutter has a tooth-angle practically the same as the thread to be produced. The thread has a lead, but the cutter has no lead; so, naturally there is a slight difference in the pressure-angle of the thread, although this is so small as to be negligible. The pitch of the thread is taken along the axis of the work and, since the cutter is parallel to the axis of the work, the distance from tooth to tooth of the cutter is the same as the pitch of the thread. If we were to tilt the axis of the cutter we would have two errors; one error in the lead of the thread and one error due to the fact that only one point on the cutter would cut a full-depth thread. It would be necessary to design a special form of cutter to cut a correct thread with a multiple cutter on a tilted axis.

A. M. DEAN:—Is the Maag gear essentially a gear of greater pressure-angle?

MR. MUFFLY:—Yes; it gives a tooth with a wide base and wholly different contour. A similar curve is shown on the involute layout in Fig. 5. Any part of the involute curve desired can be selected and a pair of gears designed to use it. If a gear blank of suitable diameter for 30 teeth were cut on a hobbing machine as a 28-tooth gear, something different from the ordinary involute curve would result. The Maag system employs a rack to generate the gear tooth and is essentially the same as hobbings, so far as tooth generation or tooth contour is concerned, although it happens that very large pressure-angles are advocated; in other words, a different part of the involute curve is used.

E. W. WEAVER:—What is the best way to produce gears commercially?

MR. MUFFLY:—That depends upon the gear which is to be produced. I am an advocate of the hobbing method and I am pleased to say that I do not meet with the opposition now that I did in former years. Summing up the experience of automobile and engine builders rather than giving my own views, which may be prejudiced, I can say that helical timing-gears are produced almost exclusively by the hobbing process. This indicates that the majority of manufacturers have found that the hobbing method produces more smoothly running gears. Quietness is of greater importance than cost, when it comes to making the front end of an automobile engine.

In transmission gears we find more difference of opinion, although it is conceded generally that the hobbing method is the most rapid. We find a number of manufacturers using the shaping machine method on account of the fact that they have step gears and the smaller gear of the step cannot be reached with a hob. This method covers the step-gear and the internal-gear fields, while the hobbing machine fills the helical-gear field covering automobile timing, turbine-reduction and cream-separator gears, and all such applications where smooth action and high speed are of first importance. Worm gears are exclusively a hobbing proposition. The only class of gear work that has not been put definitely into one category or the other is the automobile transmission. This is no doubt due to the use of the step gear and the tendency to standardize on one type of equipment. If it is necessary to use the shaping machine method on one of the gears, the tendency is to use it on the entire gear-set. On the other hand, it is generally conceded that the hobbing method gives a greater production, and the advantages of this method tend toward the elimination of the step gear to standardize on hobbing. In the meantime we have many plants divided between the two.

The matter of tooth accuracy does not enter the problem of transmission-gear production to the extent that it does on timing-gears. It would of course be highly desirable to have quiet gears in the transmission as well as in the front end, but of what value would it be to cut transmission gears as accurately as we must cut helical timing-gears when the transmission gears are to be hardened after they are cut, thus spoiling all of the accuracy? I have often been impressed by the ridiculous situation of a manufacturer who listens to the arguments pro and con of the various gear-cutter men and, after selecting the machine which he believes will split the error of the gear tooth to the smallest fraction of a thousandth, cuts his transmission gears with great care; then, when he hardens them, they twist out of shape from 0.008 to 0.010 in., making a noisy job in spite of all his trouble.

There is only one solution to this problem. For the past few years we have been doing some development work along the line of generating gear teeth with a grinding wheel after the gears have been hardened. Gear teeth have been ground with formed wheels after hardening, to a limited extent; but this method has many limitations and it is obvious that the real solution is to generate the tooth curve after the gear has been hardened. We have obtained some remarkably smooth-running gears by this method. Some of these gears are in use in high-grade enclosed-body jobs and the passenger cannot tell whether the car is running on direct drive or through the gears, unless he has an opportunity of comparing engine speed with car speed. This new machine is not yet on the market, but its introduction may lead to changes in car design. With gears of this sort the public will not be so inclined to use the direct drive all the time. The designers will be able then to offer something new in fuel economy.

JOHN MCGEORGE:—Some years ago I read an article explaining how the tooth-form should be taken in regard to helical gears. At that time I had some large gears to make. They had a 42-in. face, a 7½ pitch and were required to run as accurately as possible. They were laid out normal to the axis and not normal to the angle of the tooth. It seems to me that Trautschild was wrong in giving the form of the tooth as normal to the angle of the tooth, because the action is at right angles to the shaft. We formerly made step gears which consisted simply of several sections side by side. That was approximately the helical-gear idea. If a wheel composed of a number of thin laminated parts were cut through with a cutter and those laminations were slipped slightly until the proper angle was obtained, the helical tooth would result but, it would be cut with the tooth profile at right angles to the shaft. Why is the tooth profile made at right angles to the tooth? Is this done to suit the present cutters?

MR. MUFFLY:—First, it is only logical to use the same cutters unless there is some very good reason for making special cutters. Second, if we should begin to lay out the curves at right angles to the axis, we would need to lay out a different curve and produce a different cutter for every helix angle employed. By the present method we use one hob to cut the entire series from a spur gear to a helical gear of 80-deg. angle. Take, for instance, a four-tooth helical pinion of about 72-deg. helix angle; it has only four teeth, yet an end-view of it or a view in line with one of the teeth shows a practical form of tooth. If we laid out a four-tooth pinion of any ordinary pressure-angle, it would not be a practical form of tooth. The difference between pressure-angle at right angles to the axis and pressure-angle normal to the tooth can be cal-

culated by a method somewhat similar to the one shown for calculating the pressure-angles of worms. If we did lay the tooth out in a plane at right angles to the axis, we would need to make the correction in pressure-angle to get a practical tooth. It should be remembered also that some helical gears run on shafts at right angles or at some odd angle to each other, but we pass an imaginary rack profile between any pair of helical gears and the direction in which this rack profile moves indicates the plane on which the tooth is really acting. This plane is normal to the tooth; it simplifies matters greatly to lay out the tooth curve in this plane or to generate from a rack in this plane.

MR. MCGEORGE: — Regarding the shaping-machine method, if you referred to the Fellows gear-shaper, will you describe the cutting of helical gears on it?

MR. MUFFLY:—The Fellows machine produces helical gears by using a special cutter for each angle of tooth to be cut. The cutter in this case resembles a helical gear instead of a spur gear, as is usual on the Fellows machine. While the cutter travels up and down it must also be given an oscillating rotation about its own axis, so that the teeth of the cutter will pass through the teeth of the gear at the proper angle. This introduces a complication in the grinding of the cutter and calls for a master cam on the machine that conforms to the helix angle. The method is used only on helical gears of comparatively small angle.

MR. DEAN:—Will you describe the hobbing of spiral bevels?

MR. MUFFLY:—That process is possible, but it is not commercially practicable at present. To explain what is necessary, we must first consider a straight bevel gear which has been hobbed experimentally with a tapered hob. The hob is tapered, not merely in the ordinary sense but with an actual change of pitch, because a bevel gear changes in pitch when traveled across its face. Starting with the smaller end of the hob working on the smaller diameter of the gear, we would feed the hob along the pitch cone of the gear, introducing at the same time a longitudinal feed of the hob to bring teeth of heavier pitch into play. This longitudinal feed of the hob would require a differential rotation of the work similar to that used in hobbing a wormwheel with the longitudinal feed of hob. In addition, we must consider that the tapered hob is increasing in diameter as it feeds longitudinally; so, we must make a correction in the angle of hob travel along the pitch cone of the gear, increasing this angle to a point which will allow the pitch cone of the hob to follow that of the gear. To hob a spiral bevel gear we would need to introduce a differential action to produce the spiral, in addition to all of these factors. It does not appear that this process is likely to be developed commercially for some time to come.

MR. MCGEORGE: — Does hobbing produce a constant curve on the teeth?

MR. MUFFLY:—In any method of gear generation with a milling or planing tool, the tooth is produced by a succession of cuts which blend together to form the involute curve. In hobbing that curve is produced by a succession of lines which curve slightly in the same direction as the tooth. These are spoken of ordinarily as straight lines, because the side of the hob tooth is straight, but there is a generating action while the hob tooth is at the finishing point, and this action curves the cut slightly to conform to the involute curvature. In shaping a gear the tooth of the cutter has a curvature away from the curvature of the gear tooth it is generating, but with a slow enough feed, that is, rotating the blank and the cutter through small enough angles between cuts, this is not noticeable on the finished product.

MR. MCGEORGE:—Will it give a continuous curve?

MR. MUFFLY:—Either system generates a continuous curve so far as practical purposes are concerned. A few years ago there was considerable argument pro and con regarding the so-called flats on hobbed gears. A number of writers attempted to prove that there was something wrong with the principle of tooth generation from the rack profile. The facts are that these flats existed only in the imagination; what they saw were the irregularities resulting from a lack of experience with the hobbing process. The most common of these errors were the setting of the hob off-center, improper grinding of the hob, using a standard involute hob of small pressure-angle on a pinion with too few teeth for the unmodified involute curve, and using hobs that had been badly distorted in hardening. Except for the tooth distortion in hardening, all of these errors can be eliminated by any operator who will follow instructions carefully. The tooth distortion in the hob was overcome by the process of grinding hob teeth on the sides, after hardening. This process has been in vogue for a number of years, and there is no longer any excuse for producing incorrect gears. If we were to lay out a tooth curve by the old-fashioned method for use on a 20-tooth pinion, we would not make it a true involute curve. The true involute curve on an ordinary pressure-angle makes an undercut tooth when the number of teeth in the pinion is too small. It is therefore customary to modify the tooth-form on pinions of few teeth. The introduction of hobbing does not change the basic principle of the involute curve, so we still find it necessary to modify the tooth-form on pinions. One reason for the introduction of the 20-deg. pressure angle is that this under-cutting on the pinion does not develop so soon as it does with the 14½-deg. pressure angle. This is, however, a question of tooth-form desired, not a question of process to be used in cutting the tooth.

R. A. TOWNSEND:—How is the master form made?

MR. MUFFLY:—In making a standard involute hob, the master form is merely a lathe tool with straight sides at an included angle of 29 or 40 deg. according to whether we are making a 14½ or a 20-deg. pressure-angle hob. The master form for the old-style gear-cutter is made by establishing first the pitch-circle, then finding the base-circle and then laying out the curve as has been shown. This curve is then used as a pattern for the forming tool which is used to make the cutter that cuts the gear. There really is no master form used in connection with generated gears, except in the case of special tooth-forms such as sprocket wheels, splined shafts, ratchet-wheels and the like. On a hobbing machine the master form can be said to be the hob itself, with its straight-sided rack-teeth which generate the gear teeth directly. On the gear shaper, the master form is the same straight-sided rack-tooth, represented by the flat surface of a grinding wheel which is used to generate the cutter in the form of a gear, and this gear-shaped cutter is used to cut other gears. The gear-shaper generating process requires two steps; first, from the rack profile of the grinding wheel to the cutter; second, from the cutter to the gear. The resulting gear tooth is practically the same as the tooth generated by a hob in one step.

Fig. 12 shows a hob made up entirely of teeth each one of which is a master form for the standard involute curve on any spur or helical gears of this one pitch. These hob teeth are ground on the sides with a flat wheel. All of the cutting edges are straight lines. The method

of manufacture is first to rough out the high-speed-steel racks which are to be the inserted blades of the hob; second, placing these blades in a holder similar to the hob, but with gashes parallel to the axis and the teeth in rings instead of in thread form, we grind the sides of the teeth. This is a plain grinding operation. We merely grind rings with the required angle on each side. After the hob blades have been ground in this way, they are removed from the grinding fixture and placed in the hob body. Each blade was tilted forward during the grinding operation. When placed in the hob it is tilted back to its normal position with the cutting face radial. The gashes in the hob body are at an angle normal to the lead of the hob. When assembled in the hob, the blades are adjusted longitudinally until they check exactly for the lead on each successive tooth, in a special machine we have built for this purpose. The ends of the hob blades are then ground and the whole locked together permanently. Cutting a gear with such a hob represents the most direct form of gear generating from the involute rack, except possibly the grinding generating method mentioned earlier in connection with transmission gears.

H. G. WELFARE:—How long can a hob be used?

MR. MUFFLY:—That depends upon so many factors that I can give only comparisons. Some shops believe in grinding a hob every 2 hr. and some once a week. There is a wide variation in the speeds used in different shops. The tool cost for hobs is less than that for other types of generating machines used on spur and helical gears. This is especially true in the case of helical gears. There is not so much difference between the cost of old-style single-cutters and of hobs. I am speaking in terms of the cutter cost per 1000 gears. It has been noticed that the metal removed by one tooth of a hob during its life is greater than the metal removed by one tooth of an old-style single-cutter during its life. We also find hobs being run successfully at cutting speeds that are not considered practicable in ordinary milling practice.

It is not our custom to recommend such excessive speeds, but they are being used. As a general thing we think of a certain number of cutting feet per minute as the limit of a certain steel in a certain material, but there really is no reason why a milling cutter and a lathe tool should stand exactly the same cutting speed. On the one hand, a tooth of the milling cutter takes out its chip and makes the greater part of a revolution before it removes another chip, allowing an opportunity for coolant to flow over the tooth. On the other hand, the lathe tool, although buried continuously in the cut, is moving forward into cool metal. Hobbing is essentially a milling operation, but the hob teeth do not operate continuously in one groove as the teeth of a milling cutter do. The hob tooth has an opportunity to cool during the greater part of its revolution and, to some extent, it has also the advantage enjoyed by the lathe tool; that is, it is constantly cutting into new metal instead of going back to the point at which it took out the last chip. This distribution of heat all around the blanks is not only an advantage from the standpoint of hob life, but it eliminates one troublesome source of gear distortion encountered in other methods of gear cutting.

H. N. ANDERSON:—What is the theoretical error in cutting a spur gear with a Fellows machine?

MR. MUFFLY:—I think that the error you have in mind is not so much an error in cutting a gear as it is the error produced in grinding the cutter to sharpen it. So far as the gear-tooth generation goes, the Fellows method does the same thing that the hobbing method does, save for a slight modification made necessary by the fact that a perfect rack will generate a perfect involute curve but a perfect involute curve will not in turn afford a complete generation of the involute rack. This is taken care of in the design of the cutter, which is slightly modified from the standard involute. The gear-shaping machine representative and the exponent of gear hobbing usually argue somewhat as follows:

The latter points out that the cutter of the gear shaping machine is made with a clearance and is therefore smaller in diameter at the back than at the cutting face. Since the cutter is sharpened by grinding off the cutting face, it is gradually decreased in diameter. The gear-hobbing machine man usually makes the mistake of claiming that this reduces the pitch diameter of the cutter. This gives the gear-shaping machine advocate a chance to state that the pitch diameter of his cutter is constant, and that it is possible to cut a tooth that is all addendum or one that is all dedendum. This usually leaves the innocent bystander with about as much information as he had before. He does not know which one to believe. As a matter of fact, the cutter of the gear-shaping machine is reduced in outside diameter and in bottom diameter by grinding. It is admittedly a tooth of a different form after it has been ground, for the addendum is shorter and the dedendum is longer than before. Theoretically, this cutter tooth will generate the same gear tooth that it did before grinding, but it is shorter and will not reach in far enough to cut the tooth to the same depth that it did before. If we set the cutter in to the same depth that it cut before grinding, we upset the theory and make the pitch-circle of the cutter overlap the pitch-circle of the gear instead of merely touching it.

We sometimes hear the argument advanced that a hob also is reduced in diameter by sharpening. This is true, but reducing the diameter of a hob does not affect the form of the tooth. The tooth is cut with a forming tool or ground on the sides in a backing-off machine. The relief on the top of the tooth also applies to the space at the bottom between the teeth and to the surface on the sides of the tooth. The hob tooth has the same amount of addendum and dedendum, when ground back to the breaking point, that it had when new. A hob of a certain pitch might be ordered in any diameter that the hobbing machine will swing. The larger the diameter is, the smaller the helix angle will be. Grinding a hob to sharpen it merely reduces the diameter and increases the helix angle by a few seconds. If it is desired to be absolutely right theoretically, a slight correction would be made in the angular setting of the hob spindle after grinding the hob. In actual practice it is impossible to detect this difference in hob setting on the finished gear.

MR. WELFARE:—Does not the grinding of the hob affect the lead also?

MR. MUFFLY:—Sharpening the hob does not change the lead. It changes only the diameter and the thread-angle. Lead is a function of hob length and, since we have not reduced the length of the hob, we have the same distance from center to center of two adjacent teeth.

MR. WEAVER:—How are the gears cut that must withstand the highest duty? What process was used in cutting the gears that were used in airplane engines? I refer to the gears for propeller speed reduction.

MR. MUFFLY:—The gears used in airplane engines are mainly timing and oil-pump gears. During the war I was building airplane engines and used the hobbing method to produce all gears except one which could not

(*Concluded on page 242*)

The Design of Motor Trucks for High-Speed Service

By Charles O. Guernsey [1]

Indiana Section Paper

SUGGESTED services suited to fast trucks up to 2-ton capacity, where speed, versatility and convenience are highly desirable, are tabulated and commented upon. The evolution of the speed-truck as the result of a compromise between the delivery-wagon and the solid-tired heavy-duty truck is discussed.

Seven specific requirements for a high-speed truck are stated, a summary being given in eight divisions of the advantages obtainable through use of a truck of this type. Stating that the gear-ratio should be such that road speed will hold the engine speed within safe limits without a governor, the author outlines the type of engine needed, its design requirements and performance ability, following this with a consideration of maintenance and operating costs with regard to the possibilities of keeping them low. After a further discussion of truck equipment and gear-ratios, the author refers to his previous paper, Cushioning in Motor-Truck Design.

A summary of data contained in Department of Agriculture Bulletin No. 910, resulting from a comprehensive questionnaire widely circulated among farmers to ascertain their truck practice and preferences, is presented in the discussion following the paper.

THERE is a consistent and growing demand for faster motor trucks. The success of many motor-truck applications to various services is dependent upon the ability to cover certain distances within a definite time. Users realize that a small truck carrying, say, 1½ tons at an average of 18 to 20 m.p.h. can do as much work as a 3-ton truck that averages one-half of that speed. Then there are conditions when speed is essential because of the nature of the load. Vegetables must be delivered promptly and milk must reach the creamery before it sours. Many commodities require prompt delivery. Fast trucks up to 2-ton capacity will fit admirably into numerous lines of business, as it is indicated below. In practically all these fields, speed, versatility and convenience are very desirable and this creates a demand for high-speed trucks.

SERVICES SUITABLE FOR FAST TRUCKS UP TO 2-TON CAPACITY

(1) Marketing of general farm products, dairy products, vegetables, fruit, green stuff, live stock, grains, etc.
(2) Delivery service of department stores, furniture houses, hardware stores, laundries, florists, dyers and cleaners, butchers, bakers, bottlers, newspapers, commission merchants, wholesale grocers, etc.
(3) General hauling in express service, inter-city express, furniture moving and baggage transfer
(4) Public utilities as trouble and pickup wagons for power, water, light, gas and telephone companies
(5) National, State and Municipal uses as mail wagons, fire apparatus, salvage corps trucks, patrols, ambulances, etc.
(6) Passenger hauling as interurban buses, city bus work, charabancs and station and hotel transfer

To indicate the possibilities in saving mileage, suppose a wholesale grocery located at the center of Indianapolis requires three large trucks to make its deliveries to the surrounding country towns. The firm would need to divide its territory among those three trucks to serve it all. That would require a great amount of back-hauling and, due to the somewhat limited speed, only a comparatively limited radius, say 20 miles, could be covered. By using lighter, faster trucks and making more deliveries the firm can operate at a greater radius and route its trucks more directly. Again, there are many cases where some person is operating from a point where deliveries are required in both directions on the same day. The quantity of merchandise for some point may be small one day and the next day great. He can in such a case send more than one truck to that particular point. The important thing is that he can meet conditions as they arise and is not restricted as to capacities, distances or directions, as rigidly as he would be with slower, larger trucks.

It was impossible to meet the requirements of this new demand fully until the recent development of cord pneumatic-tires for trucks. The sizes in which this new type will be manufactured depend on the success of the pneumatic tire for trucks. Sizes of from ¾ to 2-ton capacity are now being made and, if experiments at present under way meet with commercial success, it will be possible to build trucks of 5- or 6-ton capacity to operate at a speed of 25 m.p.h.

The speed-truck that is being evolved is the result of a compromise between the delivery wagon and the solid-tired heavy-duty truck.

Almost as early as the time when the old single-cylinder engine became obsolete for passenger-carrying purposes, enterprising garage and repair men began fitting old passenger-car chassis with some sort of box on the rear end and utilizing them commercially. The next step was the marketing of delivery cars by passenger-car builders, the body usually being mounted on the standard passenger-car chassis. In some cases minor changes were made to meet the conditions better, but these vehicles have not progressed beyond the delivery-car stage, even today. In the meantime the builders of motor trucks had attempted to meet the requirements by producing a light solid-tired vehicle. These trucks retained the characteristics of the large truck to a great extent; they were heavy, slow and somewhat noisy. However, they inherited also the good qualities such as stamina, power, durability and low maintenance cost. It will be seen that the commercial cars evolved from the passenger vehicles had certain advantages and that the light truck had other advantages. There has been no truck that combined all the desirable qualities.

Requirements of a High-Speed Truck

The development of the cord pneumatic-tire for trucks now makes it possible to combine the desirable qualities of both classes previously in the field. The speed-truck must have the speed, flexibility and easy riding qualities of the passenger car, and the power, capacity, endurance and stamina of the heavy truck. In addition, it must

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have some qualities not possessed by either of its predecessors. New problems are encountered and they must be met. We believe that, to be successful, such a truck must fulfill the requirements of

(1) A sustained speed capacity of 25 to 30 m.p.h., with a maximum speed capacity of about 40 m.p.h.
(2) Sufficient ability to climb a 5-per cent grade on high gear while carrying its rated load
(3) Sufficient gear-reduction and power to slip the driving-wheels under any ordinary condition, while carrying its rated load
(4) Low operating and maintenance costs
(5) Easy riding
(6) Light weight, to accomplish item (4)
(7) Full equipment, including electric starting and lighting apparatus, an electric horn, a speedometer or an odometer, and a power-driven tire-pump

It does not appear to be necessary to justify the design and use of a truck of this new type, but a statement of a few of its advantages to the user may make the need for high-speed trucks more evident. The speed truck must comply with the following specifications if we are to give the user the advantages to which he is entitled. Some of the advantages which result in various lines of business are due to

(1) The greater number of deliveries that can be made in a day, because of higher speed
(2) The greater radius of operation that can be secured
(3) The fact that perishable commodities can be brought to market in better condition because of the saving in time and the smoother riding
(4) The ability of a 1½-ton speed-truck, as compared with a large truck, to deliver under proper conditions as much merchandise as a heavy, slow, 3½-ton truck, because of higher speed and more direct routing
(5) The possibility of purchasing two small trucks for about the cost of one truck of twice the capacity and delivering three to four times the loads because of their superior speed and maneuverability
(6) The delivery service becoming more mobile because of the smaller size of the delivery units, thus avoiding much of the extra hauling that results from serving a large territory with one truck
(7) The practicability of operating a speed-truck at less expense and with fewer stops for repairs, as compared with the older type of delivery truck
(8) The great advertising value of the quiet operation and good appearance of these trucks

Governing the Engine and Traction

The pneumatic tire makes operation at a speed of 30 m.p.h. perfectly feasible, but trucks designed originally for solid tires cannot capitalize this advantage because the engine would be turning over at too high a rate of speed. Some trucks are being advertised as speed-trucks that do not meet the conditions. They have the same engine and gear-ratio as are required for solid tires. Engines in such trucks are forced to turn over at such a high rate of speed that trouble is sure to result. These engines generally have been designed for use with a governor, and they cannot be operated safely at speeds greatly in excess of the governed speed. If, on the other hand, the gear-ratio be changed to permit higher speed, the performance ability must be sacrificed. Therefore, the speed-truck must have either an engine that can operate at a high speed for long periods or a very high gear-ratio. It seems that a compromise will result. Engines will be operated at somewhat higher speeds and gear-ratios will be higher so that, at a speed of 30 m.p.h., the piston speed will be between 1200 and 1400 ft. per min. This will depend upon the design of the engine.

This high-speed type of truck should not have a governor. The gear-ratio should be such that road speed will hold the engine speed within safe limits. The design should follow passenger-car practice in this respect. There is a difference in that although passenger cars are capable of a speed of about 60 m.p.h., they operate normally at about 18 m.p.h., or less than one-third of the maximum speed, but the speed-truck will operate at about one-half of its maximum speed. The engine of the speed-truck will be operating more nearly on full-throttle at all times than the passenger-car engine; therefore, it must be capable of operating at high speed and under heavy loads, which is a combination that is encountered in neither the heavy truck nor the passenger car. Some engine builders have considered this class of service more severe than heavy truck work.

To meet these conditions the engine must have a good oiling system and a good cooling system. It must have a thorough circulation of water around the combustion-chamber and particularly around the valves and spark-plugs. The bearings must be large, the crankshaft stiff and the cylinder walls and pistons must be fitted within very close limits. The engine must be free from objectionable vibration at all speeds, because no governor will be provided to hold the speed below one that would cause a bad period; and, due to the high gear-ratio, it must have more power than is provided in solid-tired trucks of like capacity, to give the necessary performance.

Experience has shown that, for ordinary territory, it should be possible for a truck on high gear to climb a 5 per cent hard-surfaced grade. This ability can be changed slightly by altering the gear-ratio to meet the conditions in different territories. To meet this requirement the truck must have an ability of about 0.080 according to the formula

$$A = (T \times G \times E_t) \div (r \times W)$$

where

A = ability of the truck
E_t = efficiency of the axle and the transmission in percentage
G = gear-ratio
r = radius of the wheels
T = torque of engine in lb.-in.
W = total weight of the truck, including the load, in lb.

In the case of a 1-ton speed-truck geared 5.625 to 1 and having a total weight of 5700 lb., the engine should have a torque of 1500 lb.-in. By reason of the light rolling characteristics of a properly designed vehicle of this class and because of the high average speed, it is possible for such a truck to climb on high gear short hills much steeper than the formula would indicate.

One of the great advantages of the pneumatic tire lies in its increased traction. This makes it possible for a pneumatic-tired speed truck to go into a farm field after its load. Because of this advantage the pneumatic-tired truck can operate in oil fields, timber tracts and the like, where the solid-tired truck would be helpless. Therefore, we must provide sufficient power on low gear to take advantage of this traction. The coefficient of friction between a pneumatic tire and the ground will not exceed 0.40 except on hard, rough surfaces, such as worn macadam. Obviously, extreme power is not needed on such a surface. If the wheels can be turned under conditions that require heavy torque, as in loose gravel, sand and mud, we will have provided all the low-gear ability that can be used. We have found that, on low gear, a tractive effort at the ground equal to 40 per cent of the

weight on the rear wheels is required. This is based on actual known delivered power.

Maintenance and Operating Costs

Low maintenance and operating costs are sought in all classes of vehicles and their value has been one of the weaknesses of the light delivery-trucks previously in the field. This indicates the necessity for a special effort toward improvement. We still have much latitude in this direction. The ordinary well built truck costs, during its life, six to eight times its original purchase price, for maintenance, operation and driver hire. Therefore, operating and maintenance costs must be given paramount consideration. Records show that it costs from 4.5 to 10.0 cents to move 1 ton of gross weight 1 mile, so that a saving in chassis and body weight is very important. Other things being equal, a saving of only 500 lb. will mean a saving to the user of from $1,100 to $1,800 during a truck life of 100,000 miles. Maintenance costs can be reduced materially by giving proper attention to the vital matter of cushioning truck parts against shocks and strains. This implies not only better springing, but also the use of shock-absorbing features of design throughout the chassis, such as the Hotchkiss drive, resilient frame members and flexible-fabric universal-joints. It is obvious that if the working parts are cushioned so that the brunt of road shocks is absorbed, the life of all such parts will be increased proportionately and the maintenance cost reduced.

There is no reason a loaded speed-truck should not ride more easily than a passenger vehicle. The load on the front end is so nearly constant that the springs can be made very flexible. The loaded rear-end weight above the springs is about six times the unsprung weight, while the ratio on the heaviest passenger cars is only about four. Even when running light, this ratio is about 3 to 1 for the speed-truck. With proper attention to spring suspension the speed-truck should be very easy riding and consequently easy on tires, the load, the road, the driver and the working parts of the chassis.

Equipment and Gear Ratios

The pneumatic tire permits the use of electrical equipment with perfect satisfaction. This equipment has not been accepted generally for solid-tire trucks because of the possibility of trouble due to the excessive vibration. The speed-truck will be used at all hours and operated at speeds requiring the best of lights. It will be employed in service in which numerous stops are necessary and must carry electric lights and an electric starter. A speedometer also is a necessity, because there is no governor to hold the vehicle within the legal speed limit. Power tire-pumps should be fitted on all trucks going into communities where free air-service is not available; for tires of 6-in. or larger cross-section they must be installed in all communities, as ordinary curb stations do not carry sufficient pressure to inflate these large tires properly.

Attention should be given to the problems of steering, brakes and final drive. Due to the speed, the steering and brake apparatus must be heavier in construction than that used on solid-tired trucks. To stop a truck running at 30 m.p.h. requires four times the braking effort required to stop one running at 15 m.p.h.

High axle-ratios are desirable and should probably be between 5 to 1 and 6 to 1 for a 1-ton vehicle. These ratios are well within the possibilities of spiral-bevel-geared axles. Since these axles are simpler, lighter and more efficient than other suitable drives, they undoubtedly will dominate this field, at least within the sizes named.

While the general success of the pneumatic tire in the larger sizes required on 3 to 6-ton trucks has still to be proved, there can be no doubt that their popularity on light speed-trucks will stimulate better cushioning in the larger trucks. More heavy trucks are discarded as a result of damage from excessive road vibration than of worn-out parts. The static loads on the working parts of a large solid-tired chassis are so small as compared with the shock loads, that breakage would be almost out of the question if the shock loads could be eliminated. There are many possibilities for increasing speed even in the largest vehicles without increasing this destructive vibration. Cushion tires and cushion wheels are being developed and promise excellent results. Better spring suspensions can be used. The driving line between the engine and the tires can be fitted with shock-absorbing universal-joints and engines can be mounted so that vibration from this source will be reduced materially. These points are mentioned to show that speed possibilities are not limited entirely to the light truck.

I emphasize the need for fast, economical, mobile trucks, particularly in the general-purpose sizes up to 2-ton capacity. It seems that these vehicles should combine speed, easy riding qualities, economy, durability and good performance. This requires a staunch well balanced engine; a transmission affording amply low gear-reduction; a rear axle of simple but rugged design; a light pressed-steel frame; effective brakes and good spring suspension. These units must be merged properly into a simple well balanced design.

To illustrate further the need for such trucks and why it has not been possible before to build large trucks for high speed, I refer to the photographs and drawings and their context in my paper, Cushioning in Motor-Truck Design,[2] at a previous meeting of the Mid-West Section.

THE DISCUSSION

Lon R. Smith:—To show the uses and the demand for a truck of, say, 1-ton capacity, I will read a summary made by P. J. Dasey of bulletin 910 published by the United States Department of Agriculture. It is obvious that the demand for small trucks is greater than for vehicles of large capacity, but just what capacity light truck is in greatest demand is open to question. The bulletin deals only with trucks used on farms in the States enumerated in Table 1; data regarding size and type of farm are presented in Table 2. Questionnaires were sent to 9659 farmers who owned trucks and 2314, or 24 per cent, replied. All second-hand trucks or motor units transformed into trucks, as well as all trucks owned less than six months, were excluded from the tabulation. Another 30 per cent was excluded because owners had sold their trucks, used them in commercial work only or not answered the questions in sufficient detail.

Summary of Department of Agriculture Bulletin No. 910.

The farms are of all sizes and types. The motor trucks used on them are of all sizes from ½ to 5 tons; very few have a rated capacity of over 2 tons; nearly half are of the 1-ton size.

Only 18 per cent of the farms are less than 5 miles and nearly 25 per cent are 20 miles or more from market.

Of these farmers, 95 per cent believe that their trucks will prove to be profitable investments.

Most farmers prefer the 1-ton truck to any other

[2] See The Journal, August, 1921, p. 143.

size. About 50 per cent of the owners of ½ and ¾-ton trucks prefer larger sizes.

In the opinion of these men the principal advantage of a motor truck is in saving time; and the principal disadvantage is poor roads.

They say that the trucks save from one-half to two-thirds of the time that would be required for hauling materials to and from the farms with horses and wagons; and that they have return loads for their trucks on about one-fourth of the trips.

A majority still use horses for some road hauling and, on most farms, all the hauling in the fields and around the buildings is done with horses. About 25 per cent of the men do some custom hauling with their trucks. The average annual amount received by those who do such work is $174.

For an average of about eight weeks in the year, the roads are in such bad condition on account of mud or snow that the trucks cannot be used; 75 per cent of the trucks usually travel on roads that are all or part dirt.

About 25 per cent of these men have changed their markets, for at least a part of their produce, since purchasing trucks. For those who have changed their market, the average distance to the old market is 7 miles, and that to the new market 20 miles.

TABLE 1—LOCATIONS OF FARMS

State	Number of Reports Tabulated
Maine	11
New Hampshire	11
Vermont	16
Massachusetts	63
Rhode Island	16
Connecticut	17
New York	241
New Jersey	92
Pennsylvania	235
Delaware	11
Maryland	40
Total	753

According to estimates by the owners, each of these trucks travels an average of 3820 miles per year and is used on 173 days per year.

The average estimated life of the trucks is between 6½ and 7 years; in most cases depreciation is the largest single item of expense.

Most of the owners of the ½ and ¾-ton trucks prefer pneumatic tires; the owners of 1-ton trucks are about evenly divided in their preference, but most owners of trucks larger than 1-ton prefer solid tires.

Over 66 per cent of the trucks had not been out of commission, when needed, for a single day in the year covered by the reports. Nearly the same proportion of the owners stated that they had not lost any appreciable time on account of engine or tire trouble or breakage; however, about 1 of every 30 trucks had been out of commission 10 days or more.

The average cost of operation of the ½-ton trucks was about 8 cents per mile; of the ¾-ton trucks, about 13 cents; of the 1-ton trucks, about 12 cents; of the 1¼ and 1½-ton trucks, about 19 cents; and of the 2-ton trucks, about 20 cents.

The average cost of hauling crops, including the value of the driver's time at 50 cents per hr., was about 50 cents per ton-mile with the ½-ton trucks; 34 cents with the ¾-ton; 26 cents with the 1-ton; 24 cents with the 1¼-ton and 1½-ton; and 18 cents with the 2-ton trucks.

About 80 per cent state that the trucks save hired help; they estimate that this saving amounts to $324 per year as an average.

About 50 per cent decreased the number of work animals by at least one head after purchasing trucks; however, less than 1 man in 10 disposed of more than two head. Over 50 per cent of the men whose farms

TABLE 2—TYPES OF FARM AND ACREAGE

Type of Farm	Total Number	Average Size, acres
Truck	149	64
Dairy	129	234
Fruit	113	111
Crop	48	237
General	314	210
Total	753	...

contain more than 120 crop-acres own tractors. The number of work animals kept on the farms where both trucks and tractors are owned is only slightly less than the number kept on the farms of corresponding size where only trucks are owned.

The different sizes of truck owned are stated in Table 3, as well as what sizes are considered best. These figures should be of value to everyone interested in the manufacture and sale of trucks. They point to the truck capacities best adapted to farm requirements, to the possibilities of sales of larger trucks to the present users of smaller ones, and to sales of smaller trucks to the present users of larger ones.

I suppose we have all considered that the 1-ton size is especially suitable for merchants; it was my opinion also that a somewhat larger truck than the 1-ton size was what the farmer was buying. I was surprised to find evidence in this report that the 1-ton truck seems to be in greatest use and most preferred.

G. A. WEIDELY:—Regarding the future of the high-speed pneumatic-tired truck, about two years ago it appeared that the large trucks would get most of what is known as the short-haul business, particularly in districts having so-called improved roads. For example, a company was organized to do a trucking business between Cleveland and Detroit and a number of similar companies were organized throughout the country. But they discovered that the roads would not hold up. The road from Toledo to Detroit is a fair example of that. We know that the pneumatic-tired 1 and 1½-ton trucks will run on bad roads at a fairly good speed, but that the 3 to 5-ton trucks cannot do this. It is likely to be 8 or 10 years before the various Governmental authorities learn how to build roads that will stand up under heavy-truck traffic. Until that time there should be a good field for the small high-speed truck.

B. F. KELLY:—What do these farmers mean by a 1-ton truck? I believe that the 1-ton truck Mr. Guernsey has in mind will carry much more load than the average 1-ton truck that the farmers report.

MR. WEIDELY:—The statistics quoted have to do with what the farmer wants. That is not necessarily the truck Mr. Guernsey mentions. The farmers wants a 1½-ton truck, one of 3000-lb. carrying capacity, or about the capacity of the present-day two-horse wagon universally used on the farm.

MR. KELLY:—That again is misleading. The farmer is accustomed to load 60 bu. of corn into his wagon, which,

TABLE 3—TRUCK SIZES OWNED AND SIZE CONSIDERED BEST

Number of Farmer Owners	Truck Size Owned, tons	Size Considered Best, Number of Votes
131	½	48
83	¾	62
329	1	329
63	1¼ or 1½	113
77	2	115
13	2½	...
...	2 and over	29
Total 696	.....	696

I believe, is a 1½-ton load. If that is attempted on some 1-ton trucks they will break.

MR. SMITH:—This bulletin is interesting because it covers the average load that these farmers carried on trucks of different capacity, and it at least gives a good idea of what the farmers in New England and Atlantic Coast States do with their trucks. I think it constitutes a fair criterion by which to judge the work of any user.

CHARLES O. GUERNSEY:—One of the farm journals circulated a questionnaire letter in Iowa, Illinois, Indiana, Idaho and the Dakotas, and received about the same percentage of replies as was mentioned in connection with bulletin 910. It was indicated that the farmers who had trucks above 1½ or 2-ton capacity wanted smaller ones and that those who had trucks of 1-ton or smaller capacity were interested in larger trucks. But the farmer is not willing to pay the price of a heavy truck, such as a conservative truck builder would rate at 1½ or 2-ton capacity. We have designed two high-speed trucks. One is of 1½-ton capacity and fairly heavy, with good factors of safety all through; perhaps it can be rated as of 2-ton capacity without causing trouble, but, because of its weight, the tire sizes and the power required, it costs so much that the farmer will not pay the price. The farmer will probably buy the 1-ton truck and haul 1½ tons, or whatever load he can put on it, and consider himself satisfied. The rating of trucks is variable because no two men design trucks alike. One firm is more conservative than another; a truck that one company rates as 1½-ton another might rate as 3-ton.

Mr. Weidely gave a good illustration of what happens to present-day roads under heavy-truck traffic. The roads, as they are built now, will not withstand the use of heavy trucks at high speeds. If they were kept down to a speed of 10 m.p.h. it would be all right, but it is difficult to hold the truck owner within the proper speed and load limits. The result is that a terrific impact is produced on the road.

G. A. WAHL:—The difference in vibration of trucks equipped with solid and with pneumatic tires was brought to my attention in 1917 by tests made at Langley Field by Col. A. J. Slade with two each of four different makes of trucks ranging from about 2½ to 3-ton capacity. The trucks were filled with iron bars and run over a solid road that was in bad condition. At 12 m.p.h. the solid-tired truck vibrated considerably more than the pneumatic-tired truck at 22 m.p.h. At slightly over 15 m.p.h. it was impossible to keep the iron bars in the solid-tired trucks, whereas at 22 m.p.h. there was very little movement of these bars in pneumatic-tired trucks. This was only a relative and a very crude comparison in some respects, but it showed the great amount of vibration that the truck had to endure when equipped with solid tires. There is no question that good roads are of as much importance as having trucks properly equipped. The solid-tired truck damages roads, but generally speaking the pneumatic-tired truck also causes damage at a speed of say 30 m.p.h. In the tests referred to the tractive power of the trucks in a soft field was noted, the wheels sinking into the ground about 10 or 12 in. It was surprising to find that there was practically no difference between the tractive efficiency of the pneumatic and the solid tires.

CHARLES A. TRASK:—What has been done toward regulating the tire width in relation to the total load? I have heard that township officials in the northern part of Indiana had some truck owners arrested recently for carrying such heavy loads on comparatively narrow tires that they were ruining the roads. If there are to be no regulations of this kind, it will never be possible to build roads that will endure. If 2-in. tires were put under a 10-ton truck, they would ruin any road that can be constructed, unless it were made of steel. I hope for some regulation that will compel the use of wider tires. What data have been obtained regarding a restriction of the load based on tire widths or size?

MR. GUERNSEY:—If every State presumed to legislate on this subject to suit its own needs, we would have to design trucks differently for every State in the Union to meet all requirements. In general it is conceded in many important States that 1 in. of nominal tire width is ample for each 800 lb. of load on a wheel.

A MEMBER:—Can a battery be made large enough to start a truck engine as often as is necessary in delivery service?

MR. GUERNSEY:—We have had no trouble as yet. When making frequent starts and stops, the engine is warm enough to start easily.

MR. SMITH:—We made some investigations with the idea of determining what market there was for the various sizes of our product. We used data published by the National Automobile Chamber of Commerce and by various periodicals, included our own data and compiled a table to learn how many trucks of different capacities were being built. This table checks up with the research work of the Department of Agriculture and with what Mr. Guernsey says. In 1919, 130,368 trucks were produced by organizations other than those who build their own engines, of which about 12,000 were ½-ton trucks; nine firms construct that size. About 6000 ¾-ton trucks were produced by 10 companies and 59 firms built 1-ton trucks to the number of 38,000 in 1919. The next popular size was the 2-ton truck, constructed by 71 firms; and 21,000 trucks of 1¼ to 1½-ton size were turned out by 98 different companies.

L. A. CORCORAN:—Due to the fact that a small fast truck is needed, I believe that manufacturers are resorting to the use of pressed steel in place of cast iron to cut down the weight and get practically the same strength.

MR. GUERNSEY:—That depends largely on the volume of the plant's production. In our own case there is a very decided tendency toward pressed steel and forgings to replace castings. Weight can be saved in many ways, of which changing from solid to pneumatic tires is one.

The Motor Transport Corps made an analysis of axle-center design for front axles during the war. In the case of solid-tired trucks it was ordinary practice to assume a static load of about 8000 lb. per sq. in.; in the case of passenger cars it was found that this static load advanced from 10,000 to 15,000 lb. per sq. in. and a number of very good cars averaged 12,000 lb. per sq. in. That would indicate for unsprung parts when trucks are built for pneumatic tires a saving in weight of one-third, but that cannot be carried out generally because of foundry or shop-practice limitations. In frame design for solid-tired trucks we must make the frames heavy enough to withstand the vibration and shocks to which I referred, while for pneumatic tires we take a higher figure for the stresses. So, we can actually save weight by a lighter design, in addition to adopting various other lighter parts, such as those made of pressed steel.

The Nature of Flame Movement in a Closed Cylinder

By C. A. Woodbury[1], H. A. Lewis[2] and A. T. Canby[2]

Annual Meeting Paper

DR. HAROLD B. DIXON, of the University of Manchester, the eminent English authority on combustion phenomena, has submitted a very interesting discussion of this paper, which was presented at the 1921 annual meeting of the Society. This discussion and the reply received from Mr. Woodbury are given below together with comments made by F. W. Stevens of the Bureau of Standards. For the convenience of the members a brief abstract of the paper precedes the discussion.

ABSTRACT

THE nature of flame propagation in an automobile engine cylinder has, for some time, been the subject of much discussion and speculation. However, very little experimental work has been done on flame movement in closed cylinders with a view to applying the knowledge directly to the internal-combustion engine.

It has become recognized that knocking is one great difficulty which attends the use of the higher-boiling paraffin hydrocarbons, such as kerosene, and that knocking is one of the major difficulties to be overcome in designing higher-compression and hence more efficient engines. It was desirable, therefore, to determine, if possible, the nature and cause of the so-called fuel knock in an internal-combustion engine.

The work described in this paper was undertaken to determine the characteristic flame movement of these various fuels and the physical and chemical properties which influence this flame propagation. The scope of the work is specified and the arrangement of the apparatus for measuring flame propagation is illustrated and described. Flame movement at normal temperature and pressure was then investigated, the results obtained are shown in charts and a table and these are commented upon in detail. The influences of turbulence and of temperature and pressure on flame propagation are treated in like manner, followed by a lengthy discussion of autoignition and the nature of fuel knock, which also is illustrated. [Printed in the March, 1921, issue of THE JOURNAL.]

THE DISCUSSION

DR. H. B. DIXON:—The paper is naturally of great interest to me, for I have been working on the theory of the explosion of gases for more than 40 years, and during the last 3 years have been experimenting on the combustion of the vapors of pentane, hexane, benzene, alcohol and ether with the object of obtaining data that might be useful to the designers of internal-combustion engines.

About 20 years ago I took photographs on a moving film of explosions in strong glass cylinders 9 in. long by 2½ in. internal diameter, fitted at one end with a delicate pressure indicator, and so obtained records of the spread of the flame and of the pressures registered after the passage of the spark, which itself was recorded both on the photographic film and on the pressure-card. The negatives, though fairly visible during development, made poor prints, and the pressure curves, owing to the inertia of the piston used, were comparable only for explosions that traveled at about the same rate. The photographs showed the increase in luminosity and velocity as the flame traveled from the ignition-point; they also showed the marked effect on the flames of the position of the spark, whether at the end of the cylinder, i.e., flush with the end-wall, or at a short distance from it. The indicator showed that the piston began to move when a pressure-wave starting from the beginning of the explosion was calculated to reach the piston after traveling with the velocity of sound through the unburnt gases ahead of the flame. I did not publish these results, but proceeded to attack each part of the problem separately. After my experience I can congratulate the American experimenters on the skill with which they have combined the photographic records of the movements of the flame and the variations of pressure in the explosion vessel.

In discussing the results arrived at by the authors, I may say that I am in cordial agreement with their main observations and conclusions that

(1) When acetylene-air mixtures are fired by a spark at one end of a closed cylinder, the average velocity of the flame is greatest when the acetylene forms between 8 and 10 per cent of the mixture, and when acetylene-oxygen-nitrogen mixtures are fired an explosion-wave or detonation is set up most readily when the oxygen is just sufficient to burn the carbon to monoxide and the hydrogen to steam, an excess of oxygen acting as inert gas

(2) When fired in closed vessels the flame travels with increasing velocity from the spark, but is usually checked before it reaches the end of a short tube or cylinder

(3) If the flame travels toward the end of a tube drawn out into a hollow cone the pressure may be piled up, as in the case of a tidal bore in a narrowing estuary, until even mixtures of relatively high ignition-point can be fired ahead of the advancing flame by the heat of compression. It has been shown in the *Proceedings of the Royal Society of London* that hydrogen and oxygen can be fired in this way

(4) It is not easy to set up an explosion-wave or detonation in a short cylinder, although acetylene and ethylene will detonate with air when fired in a long tube; and I do not believe that the "knocking" or "pinking" heard in gas engines is due to a true explosion-wave. In the explosion-wave the flame is traveling through unburnt gas at a constant velocity that is twice that of sound in the burning gases. Behind the wave-front the gas is moving forward en masse with the velocity of sound, and the wave-front is traveling forward with the velocity of sound in this moving medium. This statement admits of an easy confirmation, for if a sound-wave or compression-wave is made to travel through the burning gases immediately behind the wave-front and in the same direction while the explosion is photographed on a moving-film the sound-wave traces a line which is practically par-

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[2] Research chemist, Eastern laboratory, E. I. du Pont de Nemours & Co., Chester, Pa.

allel with the line of the explosion-wave, i. e., it is traveling forward through the burning gases with the same velocity as the explosion-wave. In a photograph published in the *Philosophical Transactions of the Royal Society of London*[3] the sound-wave was started too far behind the wave-front to move forward with the same velocity as the medium in which it was moving had begun to slow down; later photographs have shown that the nearer the sound-wave is to the wave-front the more nearly does it equal it in speed

In agreement with their first conclusion I have found[4] that when the explosion-wave is propagated through acetylene-oxygen mixtures there is an increase in the rate of the explosion when the oxygen is reduced from 2½ to 1½ times the volume of the acetylene, and similarly in the case of ethylene-oxygen mixtures. Moreover, the replacement of the "extra" volume of oxygen by an equal volume of inert nitrogen has a less retarding effect on the rate, as is brought out in Table 1.

TABLE 1—RATE OF PROPAGATION OF EXPLOSION-WAVE

Mixtures	Rate of Propagation Meters per sec.	Miles per sec.
Acetylene Mixture		
$2\ C_2H_2 + 3\ O_2$	2,716	1.687
$2\ C_2H_2 + 3\ O_2 + 2\ N_2$	2,414	1.500
$2\ C_2H_2 + 5\ O_2$	2,391	1.486
Ethylene Mixtures		
$C_2H_4 + 2\ O_2$	2,581	1.604
$C_2H_4 + 2\ O_2 + 2\ N_2$	2,413	1.499
$C_2H_4 + 3\ O_2$	2,368	1.471

It is an inference from these, and from similar results obtained with other carbon compounds, including pentane, benzene and alcohol, that the original burning of the carbon resulted in the formation of carbon monoxide; probably in some cases with the momentary existence of an intermediate body which breaks up as shown in the reactions below

$$C\ H_4 + O_2 = H_2\ C\ O + H_2\ O$$
$$H_2\ C\ O = H_2 + C\ O$$

The carbon monoxide formed, directly or indirectly, would then react, in the absence of free oxygen, with the steam, and an equilibrium would be reached as the gases cooled

$$C\ O + H_2\ O \leftrightarrow C\ O_2 + H_2$$

In the case of cyanogen the evidence is more direct. When the explosion-wave is propagated through the mixture in equal volumes the carbon is found, almost entirely, as carbon monoxide, and the rate of propagation and the violence of the explosion are both much greater than in the mixture with two volumes of oxygen when the carbon is found in the residual gases as carbon dioxide.

Again when a volume of nitrogen is added to the mixture in equal volumes, $O_2N_2 + O_2$, it has a less retarding effect than an equal volume of oxygen, as would be the case if both were inert in the primary combustion. Later experiments with nitrogen and argon as diluents have shown me that when the cyanogen-oxygen mixture is damped down by an inert gas the rate of the explosion-wave is not independent of the diameter of the tube, and the wave travels faster in a straight pipe of 19-mm. (0.748-in.) bore than in one of only 9 mm. (0.354-in.); but this does not affect the comparative damping effect of the nitrogen and oxygen added.

One obvious explanation presents itself, and I think it is the correct one, that carbon dioxide, if directly formed in the explosion-wave of cyanogen with two volumes of oxygen, would be dissociated at the high temperature produced. If this is the explanation it follows that the carbon dioxide found in the analysis of the residual gases from the exploded mixture, and practically all the carbon is found as the dioxide, must have been formed behind the wave-front, or while the gases were cooling. There would be consequently a longer column of reacting gases behind the wave-front since the cooling would be retarded by the gradual burning of the carbon monoxide to dioxide. That there is such a longer column I have verified by two methods, that of the "jet" and that of the "window."

In the first photographs were taken of the jets of flame thrown out from a long tube in which the two mixtures were detonated, the tube being opened just before firing. When the cyanogen was fired with two volumes of oxygen the jet photographed was much longer and more luminous than when fired with one volume of oxygen. The jet is thrown out only after the flame-front has traversed the whole column of combustible gases. In the latter method photographs were taken on a rapidly moving film of the illumination of a small window in a tube as the explosion-wave passed. When the cyanogen was detonated with one volume of oxygen the illumination was much brighter but much shorter in duration than when fired with two volumes of oxygen.

The slight lowering of the velocity of the flame of acetylene-air mixtures found by the authors, when the initial temperature was raised at constant pressure from 25 to 125 deg. cent. (77 to 257 deg. fahr.) was what I should have expected from my experiments. It was shown, for example, that the ignition-point of electrolytic gas[5] when fired by compression is the same, 526 deg. cent. (978.8 deg. fahr.) whether the gases were originally at room temperature or at 100 deg. cent. (212 deg. fahr.), although of course less compression was required to fire the gas at the higher temperature. Again the explosion-wave[6] is propagated through gas mixtures at slightly lower velocities when the gases are initially heated at constant pressure to 100 deg. cent. (212 deg. fahr.), as shown in Table 2.

TABLE 2—RATE OF PROPAGATION OF EXPLOSION-WAVE

Mixture	$2\ H_2 + O_2$	$C_2H_4 + 2\ O_2$	$C_2N_2 + O_2$
Rate at 10 deg. cent., meters per sec.	2,821	2,581	2,728
Rate at 50 deg. fahr., miles per sec.	1.758	1.609	1.695
Rate at 100 deg. cent., meters per sec.	2,790	2,538	2,711
Rate at 212 deg. fahr., miles per sec.	1.734	1.577	1.746

With regard to initial changes of pressure, Dr. Coward and I found that when hydrogen and oxygen are heated separately and then brought together, the ignition temperature is only slightly raised from about 590 deg. cent. (1094 deg. fahr.) at atmospheric pressure to 600 deg. cent. (1112 deg. fahr.) by halving the pressure; while by doubling the pressure it is lowered more appreciably to about 560 deg. cent. (1040 deg. fahr.).

Experiments on the velocity of the explosion-wave show that it is propagated at a slightly increased rate with in-

[3] See the *Philosophical Transactions of the Royal Society of London*, vol. 200A, plate 12, fig 23.

[4] See the *Philosophical Transactions of the Royal Society of London*, vol. 184, p. 1.

See also the *Journal of the Chemical Society* (England), vol. 105, p. 2646.

[5] See the *Philosophical Transactions of the Royal Society of London*, vol. 184A, p. 108.

creased initial pressure, as is brought out in Table 3, but a maximum rate seems to be reached soon.

TABLE 3—RATE OF PROPAGATION OF EXPLOSION-WAVE AT DIFFERENT PRESSURES

Mixtures	$2 H_2 + O_2$	$C_2H_4 + 2 O_2$
500 mm., meters per sec.	2,775	2,280
19.685 in., miles per sec.	1.724	1.417
760 mm., meters per sec.	2,821	2,322
29.921 in., miles per sec.	1.758	1.443
1000 mm., meters per sec.	2,850	2,319
39.370 in., miles per sec.	1.771	1.497
1500 mm., meters per sec.	2,872	....
59.055 in., miles per sec.	1.786	....

The reason an increase of 100 deg. cent. (212 deg. fahr.) in the initial temperature of the gases at constant pressure has but a small effect on the propagation of the flame is probably that the temperature of the reacting gases is but little altered.

If a gas mixture has an ignition-point of 600 deg. cent. (1112 deg. fahr.) it means that at this temperature the gases begin to heat up automatically by a flameless combustion, which increases in rate until at some high temperature, probably well over 1000 deg. cent. (1832 deg. fahr.) the flame appears[7]. With many gas mixtures the rate of combination a few degrees below the ignition-point is negligible; chemical action is slow in the pre-flame period of combustion, and only becomes rapid with the appearance of the flame itself. If the initial temperature of the gas is raised 100 deg. cent. (212 deg. fahr.) this rise is not added to the flame-temperature, but only, by giving the system a "push-off," allows the flame-temperature to be reached a little earlier. However, when the temperature of the burning gases is increased, by the passage of an intense pressure-wave through the flame, the effect on the combustion may be strongly marked, and when gases are fired by adiabatic compression the spread of the flame is as a rule more rapid, and the explosion-wave, if it can exist, is more rapidly set up than under normal temperature and pressure conditions.

Many of my photographs show, by delicate striæ, the forward movement of the gas behind the wave-front, the gradual arrest and the backward movement which takes place independently of any reflected or other pressure waves. The striations, however, become much more marked when pressure-waves are reflected backward and forward through the burning gases.

Origin of the Pressure-Waves Crossing the Burning Gases

There are several sources of pressure-waves that may be propagated through the burning gases in an explosion:

(1) The explosion-wave, set up after a certain distance of travel in a long tube, may strike the end of the tube and be reflected backward. Its rate and intensity depend on the nature of the burning gases. For instance, when cyanogen is exploded with its own volume of oxygen the chemical reaction is very rapidly completed.

$$C_2N_2 + O_2 = 2\,CO + N_2$$

The reflected wave has therefore to travel the greater part of its journey through gases in which the chemical action is little or nil. But when cyanogen is fired with twice its volume of oxygen the flame lasts much longer owing to the carbon monoxide, produced in the primary reaction, forming carbon dioxide as the gases cool.

$$C_2N_2 + 2\,O_2 = 2\,CO + O_2 + N_2$$
$$2\,CO + O_2 + N_2 = 2\,CO_2 + N_2$$

The reflected waves in this mixture are more strongly marked

(2) At the point where the explosion-wave is set up there is propagated backward a pressure-wave which I termed the retonation-wave. This resembles in many respects the reflected wave from the explosion-wave. It is easy to choose a mixture of gases of such a kind and a tube of such a length that the explosion-wave or detonation is set up just at the moment when the flame reaches the end of the tube. There is no unburnt gas to carry forward the explosion-wave, but the retonation-wave is sent backward and the reflected-wave is superposed on it, so that the pressure-wave moving backward through the only partially burnt gas is almost identical at first with the explosion-wave in velocity and violence[8]

(3) A pressure-wave, traveling with the velocity of sound in the unburnt gas, is propagated from the point where the explosion is initiated by the spark or by a small detonator. This pressure-wave traveling at constant velocity will be overtaken by the flame with its accelerated motion, if there is sufficient length of run; but if the tube is short the pressure-wave reaches the end of the tube first, and is reflected backward so as to meet the advancing flame, which, as I read the photographs, is retarded and even thrown back in some cases for a space, while the pressure-wave is being propagated backward through the burning gases, its course being now faster and marked by increased light

If the tube is of such a length that this initial pressure-wave and the flame reach the end of the tube at the same instant, the reflected waves of both are superposed, and the combined wave is comparable with a retonation-wave. This, I think, is the commonest cause of "knocking" in an explosion cylinder.

A retonation-wave might be set up at the same instant that the flame and the initial pressure-wave reached the end of the tube together. If this were to happen the combined return-wave would hardly be distinguishable from a detonation. The American experimenters differ from me as to the cause of the arrest of the flame before it reaches the end of the cylinder, and as to the source of the pressure-wave proceeding from that point. We are agreed that something runs up against the flame, or the flame runs into something that checks it suddenly. I attribute this to a pressure-wave, started by the initiation of the explosion at the spark, and continually "backed up" by the moving flame gathering speed behind it. The front of this column of high pressure, with the gas moving bodily in its wake, is reflected from the end of the tube. Whatever it is, it is traveling with the velocity of sound in the unburnt gas; I have found this to be true with gases varying in vapor density from that of electrolytic gas, 6, to that of cyanogen with an equal volume of oxygen, 21. The authors attribute the arrest of the flame to the equalization of pressure in front of and behind the flame: "When the pressure is equal the flame-front is no longer pushed forward; the propagation is arrested." They observe that the equalization of pressure should be a gradual process and they would expect the arrest of the flame to be gradual rather than sudden, as it is. But if the advance of the flame is not checked by a pressure-wave accompanied by a backward movement of the gas, I cannot understand why the flame should not

[7] See *Journal of the Chemical Society* (England), vol. 106, p. 2033.

[8] See the *Philosophical Transactions of the Royal Society of London*, vol. 200A, plate 15, figs. 44 to 51.

proceed through the high-pressure area with undiminished velocity, since high pressure, unaccompanied by movement, has little influence on the rate of propagation. The backward movement of the gas is made visible by the striæ in the flame as the pressure-wave passes backward through the burning gas, but this backward movement and the pressure-wave itself are caused, according to the authors, by the arrested flame itself.

Let me refer to a photograph that my colleague, Dr. Campbell, has recently taken and is reproduced in the lower left corner of Fig. 1. An explosion-wave has been propagated through a mixture of cyanogen, oxygen and nitrogen in a narrow tube opening into a wide one. The flame is traveling from right to left while the film is moving vertically downward. The explosion-wave is damped down soon after the flame emerges into the wider vessel, at the point marked by the white arrow, but it sends forward through the unburnt gases an intense pressure-wave which, leaving behind the slackening flame, reaches the end of the wide tube first and is reflected from it. On drawing the path of this pressure-wave from the calculated velocity of sound in the gases, it is found, within the limit of error, to strike the advancing flame at the point *A* where the flame is arrested. The flame is driven back and the striæ show that the gas itself is moving backward in the wake of the pressure-wave until the latter strikes the end-wall through which the narrow tube debouches. The wave penetrates the narrow tube, forming a line of light just visible at *B*, but the greater portion is reflected from the wall and is seen proceeding forward again from right to left until it reaches the flame-front at *C*, near the second black reference line. The flame-front is now pushed forward again, but the pressure-wave, suffering a slight reflection which is visible in the photograph, where it meets the flame-front, passes into the unburnt gas ahead of the flame, is again reflected and arrests the flame a second time at *D*, where it again passes backward through the flame, reproducing its previous action. The two points of arrest, *A* and *D*, correspond, within the limit of error, with the point where a pressure-wave traveling with the velocity of sound through the unburnt gas would meet the flame.

In the photograph shown in the upper left of Fig. 1 the explosion was started simultaneously at the two closed ends of the tube. The spark on the right being more intense caused the flame on that side to start faster than the flame on the left. An initial pressure-wave runs forward from each side, that from the right traveling farther before it meets the slower-moving flame on the left. We can see where it meets and throws back the left-hand flame, passes through it and is reflected from the closed end. On its return it checks the backward movement of the left-hand flame and hurries it forward again. Passing now ahead of the flame it is invisible until it strikes the right-hand flame which it throws back sharply, and is propagated through it to the right-hand end. The right-hand flame has meanwhile been arrested by the initial pressure-wave from the left, which passing through it is reflected from the end-wall and in its turn hurries up the right-hand flame and checks the left-hand flame. The initial flames, not being symmetrical, give rise to pressure-waves of unequal intensity. The upper part of this photograph gives a pretty illustration of the coalescence of two waves, or rather the absorption of the weaker by the stronger wave.

The photograph shown in Fig. 1 at the right gives the movements of the flame in a mixture of hydrogen with three volumes of oxygen fired by a spark near the right side of the tube while the gases were being compressed by the sudden thrust of a piston from the left. At the moment the spark was passed the gas had been compressed to nearly one-quarter of its original volume, from a column of 24 in. in length to 6 in. and of course was heated up by the compression. The pressure-wave started by the initiation of the explosion reached the advancing face of the piston before the flame, and on reflection checked the flame near the broad black shadow thrown by the clamp and traversed the burning gases to the right-hand end. The peculiarity of this hitherto unpublished photograph is that the gas was ignited by the pressure-wave at the face of the piston, or possibly in an interstice between the piston-head, which was wrapped with silk thread, and the glass tube. The flame so started by compression did not advance quickly, although it was very luminous owing to the burning of a little lanoline used as a lubricant on the thread. It was easily outdistanced by the pressure-wave reflected from the face of the steel piston. The photograph shows the comparatively slow advance of the piston which was finally arrested by a collar when it had penetrated 3 in. farther. The tail of luminosity coming from below in the center of the picture is due to the remains of the lanoline still burning when the film, which was 1 meter (39.37 in.) long, had made a complete revolution.

It will be seen from this account that I agree with the authors of the paper that there is a column of high pressure driven ahead of the burning gases in the first phase of the explosion, and that this pressure causes the arrest of the flame in a short vessel. I differ from them, it seems, in that I think that the front of this column of high pressure reaches the end of the tube and is reflected from it. When the reflected pressure-wave meets the advancing flame it checks it by its bodily motion, and itself proceeds through the burning gases with an increased speed. Perhaps we may find that our difference is mainly one of expression. Many experiments have shown that this pressure-wave travels with the velocity of sound, and I have called it, perhaps wrongly, a "sound-wave," for short.

Nearly all my photographs show the "stratification" in the flame becoming more and more marked as the pressure-waves cross and recross the tube. Sometimes the striæ appear to be driven to one side or other of the tube, leaving dark spaces. This stratification is no doubt due to solid particles, minute fragments of glass and metal, and to particles of carbon, when carbon compounds were fired, raised to incandescence and thrown backward and forward by the movements of the gas they float in. The regularity of the stratification suggests an arrangement like the dust figures in Kundt's tube when the length of the tube is not an exact multiple of the wave length.

On one other point I think my results are at variance with the authors' conclusions. They state that "The instant of maximum pressure development coincides with that of total inflammation of the gas charge." If the authors mean by "total inflammation" the fact that the flame has spread from end to end of the vessel and that the whole column of gas is visibly alight, it may happen that the pressure is greatest at that moment, but in many cases, and I believe in most instances, the greatest mean pressure occurs after the flame has completely filled the vessel. A detonation-wave, as I have shown, may be on the point of starting when the flame reaches the end of the tube. As a result a retonation-wave superposed on a reflection-wave starts back through the burning gases, and its rapidity bears witness to the high temperature and high pressure produced in it. A pressure-

gage fixed at the end of the tube from which the retonation-wave starts back would of course indicate this high pressure, and it would coincide with the arrival of the flame, completing the "total inflammation." But the retonation-wave traversing the already burning gases would bring about increased chemical action, and raise the mean pressure of the whole column of gas after the "total inflammation." In many cases the pressure-waves crossing the vessel from end to end have the greatest rapidity, indicating the highest mean temperature and pressure, some time after the whole column of gas has been ignited.

The main difference between the initial phases of the explosion and the explosion-wave or detonation appears to lie in the rapidity of the chemical action. In the initial slow phase only a few of the collisions between molecules result in a chemical change; the flame therefore persists while the gradual burning proceeds and the luminosity is small. In the explosion-wave most of the collisions between suitable pairs of molecules result in a chemical change; the flame therefore is short-lived, except where dissociation occurs, and is intensely hot and luminous.

There is still much that requires elucidation in the explosion of gases, especially as to the temperatures reached. The mode in which turbulence acts is very important in regard to gas-engine practice. My colleagues and I are trying to get photographic evidence on this in the explosion of hydrocarbons, alcohol and ether. I may take this opportunity of correcting a statement I made last year, for we have now good records of the starting of explosions in mixtures of these vapors with oxygen and nitrogen, and find that alcohol is *not* the fastest off the mark, as we thought from our first faint photographs, but is rather a slow "starter" compared with its competitors.

F. W. STEVENS:—One cannot get away from the conviction that there is after-burning; that the flame phenomena do not include all of the reaction. It seems to me that the species into which a fuel may break up necessarily have different velocity-constants, and that in the rout of an explosion they will naturally take different positions along the road, the worst wounded and slowest being the longest on the way. Yet, if we interpret correctly the sound-waves passing through these gases behind the flame, they must be homogeneous, for they show constant velocity.

The only check I have observed or interpret from any of Doctor Dixon's figures is that due to the reflection of sound from the end of tube. At the start the apparent flame-velocity is made up of the velocity within the gas plus the mass movement of the gas itself. The reflected sound-wave checks this mass movement for a short interval, even making it negative; but has no other effect upon the progressive movement of the flame within the gas than that the momentary differences of pressure may affect its velocity, by a rise of temperature.

Temperature has a profound effect upon all chemical reactions. Over the range of about 100 deg. cent. (212 deg. fahr.) where the most of the observations have been taken, the change in the velocity-constant is about 30 per cent per degree. With high temperatures the percentage-change would fall; but it would still be largely below any of the ignition temperatures, from 500 to 700 deg. cent. (932 to 1292 deg. fahr.); for very high temperatures, reaction velocities seem to be proportional to the pressure; for reactions at lower temperatures, pressure, without a corresponding temperature rise, seems to have little effect.

Since the elastic properties of gases and their densities determine their wave motion, it is to be expected from

FIG. 1—PHOTOGRAPHS OF FLAME MOVEMENT IN DIFFERENT MIXTURES

thermodynamic considerations that their reaction velocities will be closely connected with their physical properties. It seems, in fact, impossible to separate these two actions. It is greatly to Professor Dixon's credit that he has emphasized these relations. I think there are some chapters on sound that have not been written. I have seen a very nice photograph showing a reflected sound-wave from the end of a tube, meeting a flame-front where it has nearly reached constant velocity, detonation. The effect of the compression is beautifully shown by the bright spots; from which the flame-front then proceeds at a constant velocity to the end of the tube. The sound-wave is refracted as it enters the highly heated and rarified gases behind this point.

The photograph in the lower left corner of Fig. 1 looks like a most beautiful and interesting demonstration of a mooted question in sound. If the two waves finally coalesce, then they travel at unequal velocity. Is that possible? There is a short interval between them. Is it possible that this short interval furnishes enough difference of temperature to bring them into phase? Such a process could be used to measure the rate of cooling in these incandescent gases with great accuracy. Has Doctor Dixon found a new differential thermometer here? If once brought to phase, the waves will not separate again. This photograph has as much interest for the student of sound as for the chemist. There are some other interesting things about explosions in reference to sound that could be cited.

I think the expression "flame velocity" is often used to mean the velocity of combustion, which is a very different concept. Manometer readings have little to tell us about flame movement, but they give us a very considerable amount of valuable information about the rate of combustion.

The law of mass action probably acts as uniformly in quick as in slow reactions. The convenience of observing whether this is so or not is all in favor of the more common chemical processes or those largely confined to solutions where the retarding effect of the solvent and of the small temperature-range gives ample time for observation and measurement.

It is really remarkable that the major part of our laws in chemistry, certainly in thermodynamics, has been drawn from what we have supposed to be the simplest state of matter, the gaseous; yet the chemical processes taking place in gases are the least explored and determined of all. Against the bulk of other chemical reactions that we know fairly well, the percentage of gaseous reactions is almost negligible. Until there is sufficient evidence to the contrary we should look for gaseous reactions to follow the same general course as all others. Guldberg and Waage's generalization calls for a condition of constant reaction velocity to be reached sooner or later in the reaction as determined by the driving force and those in opposition. Such a phase is one of the most characteristic properties of explosions. Berthelot was the first to point it out. Guldberg and Waage came to it as a generalization from the commoner reactions. The two are probably identical and follow the same laws throughout. Berthelot's attempt to identify these velocities with molecular velocities, doubtless following the inspiration of Clausius, is interesting; there seems to be some agreements, but the facts to draw from are meager. However well the lower limit of our thermodynamic scale seems established, the upper limit is not yet suggested. Gas reactions have a range through many thousand degrees; most reactions we are familiar with, through a few tens at most.

C. A. WOODBURY:—We were gratified to note the many points upon which our conclusions had coincided with those of Doctor Dixon. With regard to our one chief point of variance, namely, the cause of the arrest occurring in the flame movement, we are still unable to reconcile our results with his conclusions. Doctor Dixon suggests that we may find our difference to be mainly one of expression. We are, therefore, planning to submit a few of our photographs with detailed calculations of our results to him for consideration. By this means we hope to arrive at a true understanding of the phenomenon.

METHODS OF GEAR DESIGN AND GEAR-CUTTING

(*Concluded from page* 231)

be reached with a hob. So far as I know, all of the gears used on the Liberty engines were cut by the hobbing method. The gear that gets the real abuse in aviation is the gear between the engine and the propeller. Such gears were used to a limited extent, and the best results were obtained from herringbone gears cut by the hobbing process. The reason for this is that the herringbone or double helical gear is best suited for the job, and hobbing is best for the production of helical gears.

Automobile timing, turbine reduction and cream-separator gears would make better examples of applications under severe service. The turbine reduction-gears run at very high speeds carrying heavy loads and, if the tooth-form is not right, they will wear out very rapidly. The other two applications do not have the severe duty to perform, but the public demands that they run quietly, which calls for the same degree of care in cutting. Practically all of the automobile timing-gears in America are cut by the hobbing process. I have not checked up so carefully in other fields, but all of the turbine gears and cream-separator gears that I have come in contact with in recent years have been hobbed.

MOTOR-VEHICLE LEGISLATION

IN the 48 States there are no less than 17 different bases or combinations by which motor-vehicle license fees are fixed. For passenger cars the horsepower basis used by 27 States is the most prevalent while for motor trucks the commonest form is the rated carrying-capacity of the truck which is used in 25 States. Other bases are: Gross weight of vehicle and load, weight of vehicle, cost, piston displacement, total tire width, flat rate per vehicle and various combinations of the foregoing, as is brought out in Table 1.

TABLE 1—DIFFERENCES AMONG STATES IN BASIS OF DETERMINING MOTOR-VEHICLE LICENSE FEES

Basis of Determining License Fee	Number of States Using This Method for Passenger Cars	Motor Trucks
Horsepower*	27	2
Carrying-capacity	0	25
Weight (vehicle only)	5	2
Gross Weight (vehicle and load)	3	7
Cost of Vehicle	2	1
Piston Displacement	1	0
Total Tire Width	0	1
Weight of Chassis	0	1
Flat Rate per Vehicle	3	2
Horsepower plus Gross Weight[1]	3	2
Horsepower plus Weight Unloaded	1	2
Horsepower plus Cost	1	0
Horsepower plus Capacity	0	1
Weight plus Cost	1	0
Weight plus Capacity	0	1
Weight plus Horsepower plus Cost	1	0
Weight plus Horsepower plus Cost plus Capacity	0	1
	48	48

[1]Basis recommended in uniform vehicle law.

In the case of a medium-priced automobile of about 25 hp., costing, say $1,700, the fees range from a minimum of $5 to a maximum of $34, while in the case of motor trucks far greater variations occur, the range being from $5 to $300 per year for a 5-ton truck. On the other hand, a flat-rate fee per vehicle, irrespective of weight or horsepower, is operative in three States for passenger automobiles and in two States for motor trucks. In only eight States is any reduction in the fee allowed for the use of pneumatic, instead of solid rubber, tires on motor trucks.

Gross-Weight Limitations

On the subject of the maximum gross-weight of the vehicle and the load combined that should be permitted on highways, State highway officials, motor-truck builders and users are far from agreement. The controversy is one of long standing and was one of the two main issues, the other being the measurement of tire width, on which the members of the joint committee on uniform vehicle laws failed to concur. As printed, the uniform law prescribes 28,000 lb. as the maximum gross-weight, but to this provision the highway members of the committee dissented. The question is an exceedingly complex one. Truck builders maintain, on the other hand, that lower transport costs are secured by the use of large truck units; highway engineers contend that the large heavily loaded vehicles are the chief agents of road destruction and that the apparent lower transport costs with the big units are actually nullified by the higher road maintenance and reconstruction charges that their use creates.

While it is not possible to quote any weight limit officially representing the consensus of opinion of State highway officials, it is believed that, except in those States where the main highways are largely of gravel or earth, the 5-ton truck is regarded as the heaviest unit for which, in the present state of the art, highways can be economically constructed and maintained. In Maryland, one of the States which have been exceedingly active both in the passage and in the enforcement of motor-vehicle laws, a gross-weight limit of 10 tons, roughly equivalent to a loaded truck of 5-ton carrying capacity is prescribed.

The extreme case of low maximum-limit is offered by Vermont, where existing laws limit the gross weight of a vehicle, except when special permits are issued, to 6¼ tons. In Colorado the maximum is 8 and in Maine 9 tons. Fifteen tons is the highest gross-weight limit prescribed, and is in force in California, Michigan and New Jersey. About 20 States place no restrictions on gross weight.

In addition to, or as a substitute for a maximum gross-weight specification, about half the States prescribe a maximum permissible loading per inch of tire width. This loading ranges from a minimum of 500 lb. in Idaho, Oregon and Texas, to 800 lb., the value recommended by the joint committee on uniform vehicle laws and adopted in a dozen or so States, including Connecticut, Illinois, Iowa, New Jersey, New York, Pennsylvania, Washington, Wisconsin, Minnesota, Massachusetts, Maine, Kentucky and Iowa. Table 2 summarizes the various weight restrictions in the State laws.

TABLE 2—SUMMARY OF WEIGHT RESTRICTIONS IN STATE LAWS

States	Gross Weight, Tons	Axle Load, Lb.	Weight Per Inch of Tire Width, Lb.	Wheel Load, Tons	Truck Capacity, Tons
Alabama	10	...	...	...	...
Arkansas	..	...	...	...	6
California	15	...	700	...	...
Colorado	8	...	...	...	...
Connecticut	..	...	800	...	...
Delaware	13	...	700	...	...
Idaho	..	...	500	...	...
Illinois	..	16,000	800	...	...
Indiana	..	...	...	...	7½
Iowa	14	...	800	4	...
Kentucky	..	...	800	...	...
Maine	9	...	800	...	...
Maryland	10	...	650	...	5
Massachusetts	14	...	800	...	...
Michigan	15	...	...	...	...
Minnesota	14	22,400	800	...	...
Nebraska	..	...	600	3½	...
New Hampshire	10	15,000	750	...	...
New Jersey	15	...	800	...	...
New York	12½	...	800	...	...
Ohio	10	14,000	650	...	...
Oregon	11	17,600	500	...	...
Pennsylvania	13	19,500	800	...	...
South Carolina	..	...	...	...	4
Texas	..	...	500	2½	...
Utah	11	...	600	3¾	...
Vermont	6¼	...	600	...	...
Virginia	12	...	700	...	...
Washington	12	22,400	800	...	...
West Virginia	11	17,000	600	4½	...
Wisconsin	12	18,000	800	...	...

Overloaded Trucks

The mere specification of a gross-weight limit is of little benefit unless some machinery is developed for its enforcement. In this respect many States are deficient. In others, such as Maryland, Connecticut, New Jersey and California, a real effort at enforcement is being made and both stationary roadside scales and traveling crews of inspectors with loadometers are employed to weigh at the roadside trucks suspected of exceeding the legal limit. Trucks loaded beyond their rated capacities are recognized by both highway engineers and motor-vehicle builders as a menace to highway transport development.

In some of the States where maximum gross-weights are specified the State highway commissioner or other official, as

TABLE 3—PRODUCTION OF MOTOR TRUCKS IN 1920

Capacity, Tons	Number	Per Cent of Total
¾	61,187	19
1	164,240	51
1½	35,424	11
2	25,763	8
2½	12,871	4
3½	12,893	4
5	6,441	2
Over 5	3,220	1
Total	322,039	100

is the case in Ohio, New Hampshire and elsewhere, is given authority to lower the weight limit at certain periods of the year when the frost is leaving the ground and the roads are soft. Without seasonal restrictions of this kind many miles of unsurfaced road would be rendered unfit for use in a comparatively short time if even a few trucks of great weight were allowed to operate over them during the spring thaw.

As will be noted from Table 3 the 1-ton truck is the prevalent size constituting 51 per cent of the 1920 production; the 5-ton truck constitutes only 2 per cent of the total output; and trucks exceeding a capacity of 5 tons represent only 1 per cent.

In a few of the States that have gross-weight limitations for motor trucks, exceptions are made in the case of trucks operating exclusively within city limits.

In addition some States place a tax on gasoline.

Future Changes Probable

State legislation governing the taxation and licensing of motor vehicles will undoubtedly undergo many changes in the next few years. The important thing now is for highway engineers and motor-vehicle representatives to work together to the end that future changes in State laws shall be just and lead to the best development of highway transport on economic lines.—From an article by R. K. Tomlin, Jr., in *Engineering News-Record.*

SEPTEMBER COUNCIL MEETING

THE meeting of the Council held on Sept. 15 was attended by President Beecroft, Past-President Vincent, First Vice-President Horning, Vice-Presidents Bachman, Crane and VanBlerck, Councilor Germane and Treasurer Whittelsey. There were also present, by invitation of the Council, V. E. Clark, C. F. Scott, C. B. Segner, L. R. Smith and F. E. Watts.

A financial budget for the current fiscal year, beginning Oct. 1, 1921, was adopted. This is based on a conservative estimate of the income of the Society for the year, the figure being slightly less than the income of last fiscal year which was somewhat in excess of $240,000. It is not the intention to curtail any of the activities of the Society that are considered of prime importance, and if necessary surplus funds of the Society will be used to defray expense of work recently inaugurated, such as that of the Research Department.

The balance sheet as of Aug. 31 showed that the net unexpended income for 11 months of the fiscal year ended Sept. 30, 1921, was $10,582.66. The income for the period was $224,875.39. The total assets of the Society were $169,151.17, these comprising general reserve of $140,641.18, which is the unexpended income accumulated in the last 10 years, and special reserves for distribution to income and expense items over the present fiscal year of $23,489.81, the accounts payable amounting to $5,020.18.

One hundred and ten applications for individual membership and two for student enrollment were approved, as well as the following transfers in grade of membership: Junior to Associate, Fred M. Brandmeier, Albert P. Lindenthal, E. J. B. Gorman; Associate to Member, Frederick L. Ortla, Warren Packard, A. M. Yocom, Carl A. Johnson, Gustaf Peterson, Irvin Fogg Richardson; Junior to Member, J. R. Bayston, H. C. Herbert, Charles LaPorte, R. S. Pfeiffer, C. E. Barton, Max L. Hillmer, Vincent Keenan, Charles H. Landon, C. A. Michel, Sherod S. Noe, George C. Rauhauser, R. H. Sanders, C. W. Sanderson, E. P. Warner, H. P. Wollensak, W. H. Worthington, Shin Matsu Yokoyama; Member to Service Member, R. S. Barnaby, Frank Walker Caldwell, Norbert Carolin, John Futhey Fox, David Gregg, Henry W. Harms, Floyd C. Hecox, James H. Herr, Robert F. Kohr, G. W. Lewis, Roy G. Miller, Thomas DeWitt Milling, Alfred S. Niles, Jr., A. Owen Seaman, Carel T. Torreson, A. V. Verville, Selden T. Williams W. Irving Chambers, F. Y. Dawson, Ernest J. Loring, William Henry Petit, Fred A. Truesdell, John J. Tucker, Gustav Wade, Herbert L. Wilson; Junior to Foreign Member, C. H. Dyke; Foreign Member to Member, G. W. Gaidzik, Frank C. Trachsel; Member to Foreign Member, George H. Bechtel; Junior to Service Member, E. V. Schaal.

Five hundred and forty-nine applications for membership were received in the first eight months of this calendar year, as compared with 948 for the corresponding months of 1920. On Aug. 31 there were 5590 names on the rolls of the Society, including affiliate member representatives and enrolled students, the corresponding figure for 1920 having been 1779.

The programs of coming meetings of the Society were considered with the result set forth in the first article of this issue of THE JOURNAL. It was understood, after much discussion, that, in connection with technical sessions in conference with representatives of the oil industry, the spokesman of the Society who might be on hand should make a strong plea for the production over an adequately long period of a gasoline of definite known characteristics. It is felt that such uniformity and consistency are absolutely necessary in connection with the design, production and satisfactory operation of automotive apparatus.

The following appointments to the Standards Committee were made, with assignments as indicated:

C. E. Wilson—Electrical Equipment Division
J. M. Watson—Iron and Steel Division
Dr. F. C. Langenberg—Iron and Steel Division
A. M. Dean—Passenger Car Division
A. E. Garrels—Passenger-Car Body Division

The following subjects were assigned to Divisions:

Engine Torque—Electrical Equipment Division
Wire Meshes—Parts and Fittings Division

W. S. Haggott was appointed a representative of the Society on the American Engineering Standards Committee's Sectional Committee on Insulated Wires and Cables.

The Special Committee on Tire and Rim Standardization, of which Past-President Vincent has been serving as chairman, reported on matters relating to policy so far as cooperation of the Society with the National Automobile Chamber of Commerce and the Rubber Association of America is concerned. The committee was given the status of a Division of the Standards Committee and it is expected that its report in the matter of tire sizes recommended for use on future designs of vehicles will be submitted for approval at the meeting in January.

Discussion of Papers at the Semi-Annual Meeting

THE discussion of the papers presented at the recent Semi-Annual Meeting of the Society included written contributions submitted by members who were unable to be present and the remarks made at the meeting. In every case an effort has been made to have the authors of the several papers reply to the discussion, both oral and written, and their contents are included in the following discussions. The only exception to this is the paper by C. A. French entitled Flame, which was printed, together with the discussion thereon, in the August issue. A brief abstract of each paper precedes the respective discussion, with a reference to the issue of THE JOURNAL in which the paper appeared, for the convenience of members who desire to refer to the complete text as originally printed and the illustrations which appeared in connection therewith.

AIR TRANSPORTATION AND THE BUSINESS MAN

BY V. E. CLARK

IN his treatment of the subject the author purposes to assist in balancing the scale of public opinion and to clarify and guide the expectations and efforts of those who are associated in the development of the aircraft industry, hoping to curb the unrestricted enthusiast, encourage the disheartened aviation devotee and arouse at least a tolerant interest among progressive business-men.

Business uses for aircraft are suggested and commented upon at some length, the impediments to commercial air-transport are stated and a safe and reliable airplane service is outlined in some detail. Three requirements for landing fields are specified and considered in connection with navigation aids and landing in thick weather. The financial aspects of aviation, Government aid and the air mail-service are discussed rather specifically. [Printed in the June, 1921, issue of THE JOURNAL]

THE NEED FOR FEDERAL CONTROL IN COMMERCIAL AVIATION

BY S. H. PHILBIN

CERTAIN fundamental legal principles applicable to aviation are first discussed with special reference to National, State and private rights, although no attempt is made to cover them in detail. Following a comprehensive statement of the importance of commercial aviation, the author excludes military aviation as being beyond the scope of the paper and describes the present situation with regard to commercial aviation in the United States.

Aircraft inspection and examination, landing-fields, air-routes and rules of the air are treated in turn and special reference is made to an aeronautical safety-code as being highly desirable. The character of a suitable administrative body is outlined, seven specific desirable definitions of its authority being given. In conclusion, the statement is made that there is urgent necessity today for a carefully formulated and well administered plan of Federal legislation that will care for the immediate and future requirements of the aviation industry. [Printed in the August, 1921, issue of THE JOURNAL]

THE DISCUSSION

CHAIRMAN J. G. VINCENT:—It is interesting to me to note that Mr. Clark and Mr. Philbin, writing on different subjects from different points of view, arrive at exactly the same conclusion as regards the desirability of proper control. It is absolutely necessary to have control.

A MEMBER:—It was not until after the automobile really had become a commercial success that we began having good roads; perhaps we must get airplanes into service before we can hope to get municipal support for landing-fields.

CHAIRMAN VINCENT:—That is a good point, but probably the two must come together more closely than the automobile and the roads did. The automobile could get along on a poor road; it was more a matter of discomfort than of inability to get there. I believe that there is a movement all over the country toward landing-fields.

I think there is nothing that will interest the cities in voting landing fields so much as the air mail. A municipality will make great inducements to have the air mail routed to its locality.

F. E. MOSKOVICS:—I wish to challenge Mr. Clark's point of view. I believe that he has not touched upon what seems to me the most important factor of the present state of the art. If we study the business hisory of the world, we find invariably that the country that has the best means of transportation leads in culture, intellectual progress and development, and is invariably the material leader of the world. I shall not review ancient and modern history, but it shows clearly that the intellectual advancement and the culture of a country are in a direct ratio to the rapidity with which transportation can be accomplished between two points. In other words, the rapidity of interchange of thoughts and commodities and people goes hand in hand with progress. No one will argue against the fact that, within certain limits, the airplane is a practical and safe means of transportation. It seems to me that we must inspire men with the thought that, if they will come into this great enterprise, possibly without the chance of making money immediately, they will do about as patriotic and as great a thing for their own Country and for humanity as is possible.

About 18 months ago I received a telephone message at

noon from the commanding officer at McCook Field, 116 miles distant, that it was important for me to see some papers that were to be sent to Washington at 5:00 p. m. that day. I had to leave on a train at 4:00 p. m. for San Francisco. Capt. T. H. Bane said he would send the papers over within an hour by airplane. While I was at lunch a telephone message came that Mr. Clark and Major Schroeder had flown that 116 miles in about 40 min. The sun was not visible at any time during the flight and a sleet storm began before the day was over, but they returned to McCook Field. I could not possibly have seen those papers except for airplane transportation. Can anyone believe that the world does not want that kind of transportation? If not, it is the first time in history that a fleeter means of communication did not supersede a slower.

It seems to me that we should establish what might be called a bureau of propaganda to blazon the truth. The people and promoters who have the attitude of untruth in their statements are doing the greatest injury to aeronautics today. To promote a company simply to provide airplane travel for short distances where rail transportation is easy, is absurd. I think there is more activity on the Pacific Coast in the way of flying than in any other part of the United States. The fastest railroad train between Seattle and San Francisco makes the run in about 32 hr. The slow schedule is due to two mountain ranges and other natural barriers. The distance is about 800 miles in an air-line and the weather is fine during practically all of the year. An airplane today can make that flight easily in either direction in 8 to 9 hr. The forest airplane patrols work practically every day. The rainstorms are pretty much localized and the pilots navigate around and over them. Landing fields are already established practically 100 miles apart. A man drawing a $25,000 annual salary can afford to spend $200 for that trip, and an airplane that could carry five men at $200 each for the trip could make a profit.

CHAIRMAN VINCENT:—As Mr. Moskovics indicates, the airplane can be made a commercial success first as a means of transportation in those localities and under conditions where the present transportation facilities are not good, either by reason of the lack of railroads or steamship lines or because of the circuitous route that may be required. It is possible to find opportunities of that kind in the United States, and it is very important to bear this in mind.

W. E. WILLIAMS:—The steel passenger-car was put into use on the railroads of this country at a tremendous expense just to eliminate the thought of being burned up in a railroad accident. We have not appreciated fully the necessity of eliminating the danger of airplane fires. If we can construct the machines so that they will not burn up even though they fall, we will have made a greater stride to command public favor than can be accomplished by any other one line of improvement.

CHAIRMAN VINCENT:—There are plenty of engineers who know how to build airplanes that cannot be set afire.

S. H. PHILBIN:—We do have fire accidents now and then, but they are almost exclusively in the Government service. The public does not know what causes those fires or that the fire hazard is not equally existent in commercial airplanes. There is always a fire hazard wherever kerosene or gasoline is used, in a kitchen or in an airplane. The public must be told the truth about aviation. There are two practical ways of accomplishing this. Aviation is not yet full grown. We know that it will develop and that all the difficulties will be swept away when there is a public demand and we have quantity production, as was true of the automobile industry.

V. E. CLARK:—The fire risk is not a thing that the flyer fears much. For every thought he gives to fire he gives a thousand thoughts to the danger when he is getting into or out of a small field. Of course, a fire can be induced in an airplane, the same as in an automobile. Gasoline connections can be bad enough that grave danger of fire results, or gasoline tanks can be located and arranged so that fire will result in case of a crash.

CAPT. H. E. HARTNEY:—The solution of commercial aviation is not so far distant as one might be led to believe. Comparatively speaking, it is held up by only a few minor problems at present.

There is not one single commercial airplane operating in this country at present. If every airplane we have were destroyed and replaced by an uptodate commercial machine, commercial aviation would be established on a sound basis within two years. The by-products of flying, mainly the fruits of the operations of the aerial camera, would go a long way toward paying the overhead of the operating companies and leave a good margin for transportation of cargo and passengers.

It is not sufficient that cities and towns have landing fields; they must be linked into a well-organized system of airways. Belts of emergency and auxiliary landing-fields corresponding to highways and railroads must be established so that airplanes traversing the Country will follow routes just as steamers follow certain lanes across the ocean. The permanent establishment of municipal landing-fields throughout the country is in itself an impediment to aerial transportation. The sooner those interested in aeronautics make a bid for airways rather than unrelated landing-fields, the sooner the docking requirements of airships and airplanes will be solved and regular air-transportation schedules become operative.

REQUIREMENTS OF AERONAUTIC POWERPLANT DEVELOPMENT

BY G. J. MEAD AND L. E. PIERCE

IN discussing the probable trend of aeronautical powerplant development and subsequent to a brief survey of the present situation, the authors review the evolution of various engine types and analyze the effect of their characteristics on airplane performance, considering also the proper installation of airplane powerplants. The problem now confronting the industry is one of establishing standard types for the powerplants required by each service and setting up reasonable power requirements for each unit. For each service, factors must be developed to permit the making of correct comparisons of the performance of the different engines.

The future types of engine are considered at some length and special reference is made to radial engines. Curves and tabular data accompany the discussion of variations in engine elements and the characteristics of a high-speed airplane are treated in a similar manner.

Following a lengthy review of the factors that should govern powerplant installation, a summary of the paper is presented in conclusion. [Printed in the July issue of THE JOURNAL]

THE DISCUSSION

E. A. SPERRY:—One of the enemies of aviation is the fire risk. Many aerial accidents have been caused by this within the past two years, and the horrible part is that so many of our fine pilots have actually been burned to death. The airplane always vibrates more or less and there are always nodes in those vibrations; some joint in the gasoline system will spring a leak and fire has in many cases occurred from the exhaust or from the electric ignition system. Almost invariably a fire will occur following a smash-up. The aviators often would have time to extricate themselves were they not confronted with a sheet of flame that not only smothers the pilot but envelops hundreds of square feet all around him. In such instances the pilot is asphyxiated immediately.

Some believe that we ought to run aircraft on nothing short of some kind of fire-extinguishing fluid; that we ought to use something that will not burn, heavy bunker oil, used under the boilers on ships; not Diesel-engine oil, which costs about the same as kerosene, but bunker oil. When some of it is evaporated to dryness, as high as 21 per cent of solids remains in the bottom of the flask, but it passes through the Diesel-engine cycle perfectly clean; its exhaust is odorless and colorless; it has 25 per cent more British thermal units than aviation gasoline, and much less is used for a given power. That oil is a fire extinguisher.

Because of a circular that came to me not long ago, I sent for samples of a trade compounded metal. Take, for instance, metals heavily alloyed with magnesium. I found some that have a 60,000-lb. tensile strength, but there is an admitted trouble in that the shavings are very inflammable and might catch fire under a lathe, for example. We were told not to use water on those shavings if they caught fire. In Frankfort, which has the largest factory that handles this material, their practice is to have a pail of fuel oil available; they dash the oil on the metal shavings in case of fire and it immediately extinguishes the flames.

There seems to be no ordinary way to set this fuel on fire. McCook Field has tried it with every kind of incendiary bullet, even those magnesium bullets that will set the most non-inflammable gasoline-tank on fire. It is impossible to do any such thing with that oil; in one instance it was made to smoke when a thick rag was saturated with it. The rag was hung up and a number of incendiary bullets put through it; but that was the nearest approach to a conflagration that we could get. Of course, gasoline will spring into flame instantly.

If we could use the Diesel cycle, we would accomplish many things all at once. We could eliminate the fire risk, use a considerably smaller percentage of fuel, get a very much higher thermal efficiency and a gallon would carry us much farther. The trouble with the Diesel engine is that it has been so tremendously heavy up to the present. It seems almost impossible, but we have found what appears to be a way out of the difficulty. We have obtained now about 3000 hr. of operation of the machine; I think our series of cards consists of more than 2700. The construction has gone through many changes, the principle is established and we have thrashed out many of the necessary refinements. The Diesel engine has been described as a mountain of cast iron with a little driblet of power issuing at one end. This is very well illustrated by the fact that the standard Diesel engines of today weigh from 250 to 500 lb. per b.hp.

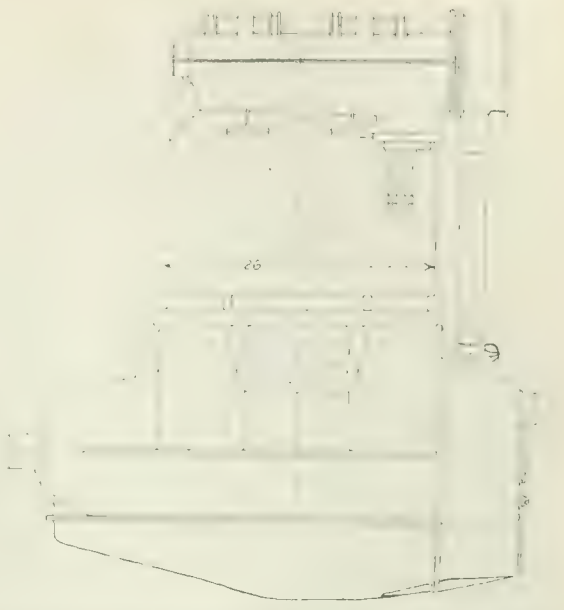


FIG. 1—ONE UNIT OF AN AVIATION ENGINE USING AUTO-IGNITION AND HEAVY FUEL-OIL

Fig. 1 shows our development of one unit of an aviation engine using auto-ignition and heavy fuel-oil. This engine consists of two high-pressure cylinders separated by a low-pressure cylinder. It is built about as small as we dare to build a Diesel engine; that is, 5 x 7 in. As compared with a two-cylinder Diesel, simply by separating those two high-pressure cylinders and putting a low-pressure cylinder between, we get in this engine about six times the power. This engine has 6 to 1 high and low-pressure cylinder compression ratios. The first engine, without many refinements still to come, works under 5 lb. per hp., which represents a large gain in power for a given weight.

Fig. 2 shows a working drawing of a 10 to 1 compound engine, showing the internal arrangement. The crankshaft is sturdy. The two outer cranks are down. The low-pressure crank is in the center and is shown in the up position; the engine is thus balanced very per-

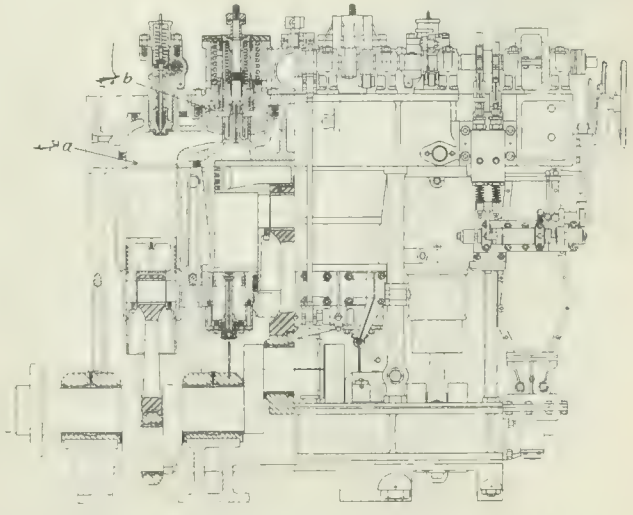


FIG. 2—WORKING DRAWING, PARTLY IN SECTION, OF A 10 TO 1 COMPOUND ENGINE

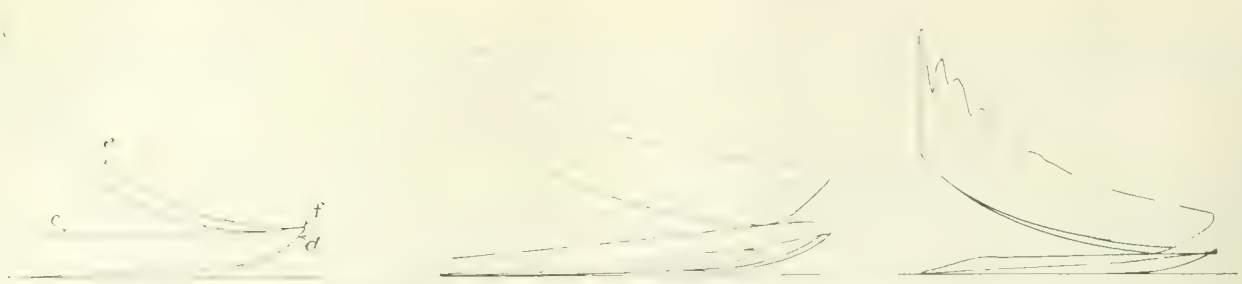


FIG. 3—THREE INDICATOR CARDS OBTAINED FROM THE ENGINE SHOWN IN FIG. 2
From Left to Right These Are a Cyclic Card without Fuel, a Card Showing the Range of Control from 10 Per Cent Overload to Idling by Regulating the Amount of Fuel Injected and a Card Showing a Straight Detonation

fectly. The high-pressure pistons are down and the low-pressure piston is up. The under side of the low-pressure piston, outside the trunk, is utilized as a pump for supercharging or delivering first-stage pure-air.

Through supercharging, this Nation owns the ceiling of the world on account of the fine work done at McCook Field. We get our high Diesel-engine pressures and temperatures by the fact that we do it in two stages. If one attempted to procure an air-pump capable of developing a pressure of 515 lb. per sq. in., the manufacturer would never think of making a pump to do this in one stage, but would ask how many stages were wanted. Fig. 2 shows a two-stage compression which gives wonderfully good results.

The trouble with the Diesel engine is that it has only a very slight amount of oxygen to work upon at high pressures, and that amount for only an instant. This makes it very heavy in comparison with its power. The clearance space is about one-twentieth of the piston displacement, and that indicates the total amount of oxygen that a Diesel has available. That is the disadvantage of its weight; it is designed around a very small amount of oxygen shown under the dotted line *A*, whereas, in the compound, we have a very large amount of oxygen to work with because of the very large dome representing the clearance or combustion-space above the high-pressure piston. Having such a large amount of clearance, we are enabled to supply both high-pressure pistons and then go right over to the low-pressure piston and follow it to the end of its stroke with pressures still above that of the atmosphere. The two high-pressure cylinders are four-cycle, one being 360 deg. behind the other, so that a power stroke in one high-pressure cylinder is followed by a power stroke in the low-pressure cylinder; then the other high-pressure cylinder likewise supplies the low-pressure cylinder on its next down-stroke. Every down-stroke of the low-pressure piston is a power stroke, and we get a true four-cylinder action by using only three cranks and two fuel-valves. Solid fuel-injection is used, eliminating entirely the high-pressure three-stage air-injection pumps for the fuel. The fuel-valves are located over the center of gravity of the large dome of the combustion-space.

The combined induction and transfer valves are directly over the short transfer port connecting the high and the low-pressure cylinders. The supercharging pump is below the low-pressure piston-head and surrounds the trunk. Semi-circular rows of intake and discharge valves are in the annular floor of the pump. The compressed air is delivered to the cored passage *b* in the valve casing and intensely cools the large ribbed upper surface of the transfer valve and stem on each air induction, washing these surfaces on each induction quarter of the four-stroke cycle, which immediately follows the transfer or heating period. The charges to the low-pressure cylinder alternate from the two high-pressure cylinders, as stated.

At the left of Fig. 3 is a tracing of the cyclic card of the compound without fuel. This shows the first stage of compression from the pump driving the piston during the induction stroke *C*, the mean effective pressure being considerably greater than in the standard Diesel; it is about 111 lb. per sq. in. in the engine having the 10 to 1 ratio. The induction valve closes at *d* and the compression proper starts from this stage and attains 515 lb. per sq. in. on the line *e*. Receiving no fuel, it comes down on nearly the same line and passes through the transfer valve *f* into the low-pressure cylinder and down below the atmospheric line somewhat before the exhaust-valve opens. The exhaust is refrigerated in a cold engine when no fuel is supplied and stands at 6 to 10 deg. cent. (42.8 to 50 deg. fahr.).

This engine is controlled by regulating the amount of fuel injected. The card reproduced in the center of Fig. 3 is from a 10 to 1-ratio compound, showing the whole range of control from 10 per cent overload to idling. From the top of the compression curve to the left, the horizontal line of combustion indicates the ordinary slow Diesel burning. In the Diesel cycle employed in the compound, a constant quantity of air is always compressed and just enough fuel is added at the upper dead-center to do the work. Combustion is always complete and the efficiency is very high.

The view at the right of Fig. 3 shows something contrary to the general theory that to get a quick rise of pressure it is necessary to anticipate the fuel-induction point and put the fuel in with a considerable lead. The compression-line proper has here gone to its peak to the left and started back before the fuel induction has taken place, showing that a quick rise of pressure has nothing whatever to do with the timing of the fuel injection. This has to do with another matter also, in that instead of having the expansion ratio of ordinary automobile engines, from 4 to 1 as compared with the Diesel's 12 to 1, we are enabled here to get an expansion ratio of 120 to 1, and make a very great gain. We have been able to couple up supercharging with super-expansion and yet retain very low weights.

It will be recognized that the card at the right of Fig. 3 is a straight detonation card, but it gives a very good idea of just how the cycle works throughout. It cost much time and money to accomplish it, but we have found how to detonate almost any fuel. We can take doctored fuel that is guaranteed against detonation and detonate it with perfect ease in this cycle. While automobile engineers have been trying to dodge detonation, we have been trying to harness it and put it into service. It is very useful because it piles up the heat as far from the exhaust-valve as possible. In a Vickers engine we have only about 95 deg. of crankage available be-

tween the time of the cut-off of the fuel and the opening of the exhaust-valve. But, by detonation, we pile the heat just as far away from the exhaust-valve as possible, and we have to go some 310 deg. before the exhaust-valve opens. So, we conserve the power gases. The consequence is that we are able to turn a larger percentage of the exhaust gases into useful effort on the crank and the exhaust is cool, just as it should be. Instead of the 60 to 70 lb. per sq. in. net mean effective pressure to the crank of the Diesel, with the compound we are enabled to get from 600 to 700 under conditions of very much better distribution than in the Diesel, namely, two strokes that succeed each other, each having half of these effective pressures reduced to the ordinary standard, that of the combustion cylinder area.

R. W. A. BREWER:—So long as the subject of fuel and its preparation for use in the engine is relegated to the background, so long shall we be faced with the fire risk. In view of the very high state of development to which the modern automobile engine has been carried, we ought to benefit by this development as an engine proposition and turn a certain amount of attention to the use of fuel which does not carry with it this fire risk. There are two lines of development to which attention is called. One is that when carrying on demonstration for some Roumanian chemists on what was called solidified gasoline, about 10 years ago, it appeared to be a most suitable fuel for aeronautic purposes because it actually was gasoline formed into a jelly. This jelly contained only about 0.5 per cent of foreign substances, which did not in any way impair or interfere with the combustion of the fuel, because it was precipitated out after the fuel had gone through the tank. The fuel was absolutely safe because there was no spillage and a piece of it lighted with a match would burn like a candle. The only way of using it was under a small pressure that squeezed it out as liquid squeezes out from a sponge.

To prepare the fuel, ordinary gasoline received a temperature treatment, some stearic acid and wax were added and a kind of suds was formed, which was allowed to cool, the operation only taking about 30 min. This emulsion, in its solidified form, was cut into cubes of any convenient size and put into the tank. That is all there is to it. In the tank the vapor was utilized in the ordinary way. The only amount of inflammable vapor in the whole system was what was contained in the pipe that led from the tank to the engine. That seems to me a very simple sort of solution of this fire-risk problem.

Alternatively, there is the use of a fuel which is non-explosive at ordinary temperatures and under usual conditions. Much attention has been drawn lately to the methods of preparing such a fuel for use in an internal-combustion engine, because gas is what drives the engine, not liquid. If we consider the modern engine a gas engine, we can now almost wipe out the loss of volumetric efficiency that we know is occasioned in feeding an engine with gases, distinct from liquid, by reason of the supercharging devices, or forced induction systems, that have come very much to the fore lately. An aviation engine is a gas engine and, if it is treated as such, we shall surmount many of the difficulties, particularly those due to fire risk.

MR. WILLIAMS:—Mr. Sperry has described possibilities that should be studied very seriously, not only for the aviation field but all fields where the internal-combustion engine is used.

CHAIRMAN VINCENT:—Messrs. Mead and Pierce have compiled in one paper much valuable information which is more or less the result of the activities of the engineering divisions of the Air Service and the Navy. Those branches of our Government service are doing a great amount of development work that is very valuable. Some of the work is not necessarily of particular value in itself, but in such instances they are trying to determine what things should *not* be done. This paper refers to the practical number of engine cylinders and mentions the fact that engines having 18 cylinders have been made. That is being done for the purpose of determining what is the most practicable combination of cylinders. Only the Government can do such work. The same thing applies very largely to radial and air-cooled engines. The Air Service officials know that such engines are practical in certain sizes, but they do not know where the limit is and they are trying to determine it. This paper is important as giving a résumé of what the situation seems to be to date. The work is being continued and, naturally, development will change the situation from time to time; it has many angles.

NEIL MACCOULL:—What fuel economy does Mr. Sperry obtain with the engine he describes and what maximum speed has he secured so far?

MR. SPERRY:—We approach 0.42 lb. per b.hp.-hr. in rather a crude construction. We know much more now than we knew six years ago when the engine was designed. As to speed, we seem to have no limit, especially with regard to the performance within the cylinder. An engine of this type has run 1600 r.p.m.

C. E. SARGENT:—In connection with Mr. Sperry's description of this new Diesel cycle, it occurs to me that the same economy can be obtained with the single expansion engine as with the compound, especially in gas-engine practice. We compound a steam engine on account of the cylinder condensation. We do not have this to contend with in gas engines. Experience with stationary engines shows that expansion to atmospheric pressure gives the same economy that is obtained in a Diesel engine, even with low compression. Mr. Sperry has given us a wonderful start toward fuel economy, for aeronautic, automobile and tractor engines, which we must meet very soon if we expect to maintain the automotive industry.

MR. SPERRY:—Our view of this compounding of the steam engine is exactly the reverse of Mr. Sargent's. We believe that condensation is the greatest enemy to compounding. Because of the fact that we have no such thing as condensation in the internal-combustion engine, we will have a much richer reward than was ever possible in steam compounding. In reciprocating steam-engines compounding stops at about 15 to 1 to 18 to 1. Here is an engine that already has run about 120 to 1. We gain more by compounding an internal-combustion engine than by compounding a steam engine because we have a very much greater range of pressure at our command. The American Society of Mechanical Engineers appointed a committee last winter to see whether boiler pressures could not be increased to provide more pressure for compounding. Here we have already in hand a pressure of 1000 lb. per sq. in.

Although we hear much about the safety of aircraft against fire through the ignition of gasoline, the constant recurrence of the burning of planes and the loss of life through fire, especially at the time of smash-up, emphasize the importance of eliminating the fire risk.

MR. BREWER:—The subject of the compound gas engine was threshed out years ago. Owing to the low specific heat of the exhaust gas of a gas engine, there is absolutely no object or advantage that can possibly be ob-

tained from a further expansion of exhaust gas in a separate cylinder in a gas engine. The waste heat from the exhaust of a gas engine is of practically no value except for ordinary heating.

A. D. T. LIBBY:—Discounting the reliability aspect of the ignition, what has been found regarding increase of power in the use of two, three or four-spark ignition on these multi-cylinder engines?

CHAIRMAN VINCENT:—I am now conducting experimental work on a large six-cylinder engine which is very much like the engine that is described in the Mead and Pierce paper for dirigible work. This engine has 6⅝ x 7½-in. cylinders and is a four-valve type. As pointed out in the paper, for dirigible work fuel economy is of much more importance that low weight; naturally, no unnecessary weight is added. The engine has just completed a 50-hr. test. Knowing that detonation would be one of the chief troubles in that engine, we provided four spark-plugs, spaced as nearly equally around each cylinder as possible without having the spark-plugs in adjacent cylinders dangerously near to each other. We found that with the four spark-plugs in good condition and with proper ignition, detonation was reduced very materially. We found, however, that we could not go above 5 to 1 compression-ratio without severe detonation. During the 50-hr. test, which was run with a 5 to 1 compression-ratio, there was a slight detonation at times. It seemed to occur in cylinders Nos. 2 and 5 more frequently than in the other cylinders and, was, I believe, due to poor gas distribution. We tried a 5½ to 1 compression-ratio with the four spark-plugs and could not operate the engine without using benzol. It was very interesting to cut-out just one of the spark-plugs; the engine would detonate terribly. In my opinion, it is absolutely necessary to have at least four spark-plugs in a large engine of this type, unless one can be placed in the middle of the cylinder-head or some other arrangement made that we did not find possible. The engine seemed to act just about as badly on three as on two spark-plugs, due, no doubt, to the way the spark-plugs were arranged. The cylinders were very well cooled.

MR. LIBBY:—Did the detonation you describe occur at any particular speed?

CHAIRMAN VINCENT:—The engine was running constantly at a speed of 1400 r.p.m.

A MEMBER:—What is the principal deterrent in this country to the development of the stationary-cylinder radial water-cooled engine? Why has it not been developed as much in this country as in Europe?

L. E. PIERCE:—We are starting the development of the stationary-cylinder radial air-cooled engine; it is still in the experimental stage. I think the water-cooled engine will come second if the air-cooled engine develops successfully. I believe that the radial engine of high horsepower will not be very adaptable in aircraft development.

CHAIRMAN VINCENT:—The air-cooled engine is made radial because of the necessity of such construction for cooling purposes rather than that the arrangement is particularly desirable from an airplane point of view.

I think that the danger from fire hazard has been exaggerated. It is necessary to have a good engine to design an airplane, and necessary for the airplane designer to know something about how that engine should be installed. With our present knowledge we can design for an airplane a really reliable powerplant installation, or installations, as the case may be; and it is possible to build an airplane that cannot catch fire except through gross carelessness, machine-gun fire or the like. When flying an airplane, I have no more fear that it will catch fire than I have that an automobile will catch fire when driving it. With a modern airplane engine, properly installed, there is absolutely no danger from fire. Where the engineer really has a chance to do a good job, he installs the engine so that it cannot cause fire, even if the fuel pipes break.

L. M. GRIFFITH:—The statement that "the power required to overcome the inertia of the reciprocating parts increases rapidly with the increase in the cylinder bore at a given speed," is evidently incomplete, inasmuch as the increase in power is not directly the result of the increased inertia but is due to the increase of friction resulting from the increased bearing load caused by the higher inertia forces. The authors undoubtedly appreciated this distinction, but it occurs to me that a clarification of the statement can do no harm. As a matter of fact, the friction losses in fully lubricated sliding bearings are dependent almost entirely upon the sliding velocity and the nature of the lubricant, any increase of the unit load having a negligible effect so long as the lubricating film is maintained. This indicates that the increase of shearing velocity in the oil-films at the several bearing surfaces is of much more effect in increasing the mechanical losses of the engine than is the increase of bearing load due to increased inertia forces.

It is noted that the authors' discussion of the rotary type of engine is limited to the single revolving-cylinder type, the double revolving engine not being mentioned. Nevertheless, the latter type has many important advantages for certain classes of service, inasmuch as the power output can be approximately doubled by this means, without any increase of the head resistance. The double revolving engine is readily operable at speeds of about 2500 r.p.m., the propeller being driven at one-half this speed without extra gearing.

No mention is made of the barrel-type engine, in which the cylinders lie parallel to and drive a simple shaft by one or two so-called swash-plates. This omission is important, as the barrel-type engine has many important advantages such as extreme compactness, relatively light weight, low head-resistance, mechanical simplicity, ease of installation, perfect mechanical and impulse balance and extreme accessibility. These characteristics make this type of special value for multiple-engined airplanes where the power units are mounted in nacelles or in the leading edges of thick wings. From the military standpoint the type is of decided interest due to the fact that gun-fire can be directed through its simple hollow shaft without necessitating a synchronizing gear.

The relation between engine weight and fuel economy does not appear to be expressed exactly correctly in the paper. If a reduction in the fuel consumption of 1 lb. per b.hp.-hr. necessitates an increased powerplant weight of 1 lb. per b.hp., the total mean weight of powerplant and fuel will be equal in the two cases for a flight of 20 hr. and not 10 hr. as stated.

S. D. HERON:—In view of the many broad statements at present finding utterance in this country regarding air-cooled aircraft engines, it seems that an investigation of the present state of knowledge is justified. Frankly, I am biased in favor of the air-cooled engine, but I am not so prejudiced as to be unable to grant that water-cooling has advantages, or to claim that air-cooling has reached the pitch of development of water-cooling. Positive statements regarding air-cooled engines are made in the paper to the effect that:

(1) The parasitic resistance of the air-cooled engine is

considerably higher than that of the water-cooled engine
(2) The reduced vulnerability of the air-cooled engine is of little practical military advantage
(3) Air-cooling at present allows of only relatively low mean effective pressures
(4) Air-cooling does not allow of easy temperature control
(5) The weight comparison of the two types is not favorable to the air-cooled engine

Little evidence regarding the relative resistance of air and water-cooled units seems to exist; if it does exist, it is by no means widely known. The only figures I have been able to obtain are that the engine and body resistance of an RE-8 machine with a 150-hp. RAF-4A engine, which is a 12-cylinder air-cooled V-type engine with a scoop cowl, is 53 lb. per sq. ft. and for an RE-8A machine with a 200-hp. Hispano engine, which is exactly the same as the RE-8 machine except for the engine, engine fairing and cooling system, it is 66 lb. per sq. ft. Both of these values are from a Royal Aircraft Factory report and are at 100 ft. per sec., and for tests on one-fifth-scale models.

It has been stated on good authority that model tests have shown that the resistance of an air-cooled radial engine is somewhat higher than that of a water-cooled 8-cylinder V-type engine but, on the other hand, full-scale tests on the Sopwith Snipe and Nieuport Nighthawk have shown a level flying speed of over 140 m.p.h. at a 10,000 ft. altitude, this performance in the case of the former being obtained with an engine that was not giving more than 280 hp. on the ground, and probably less, which seems to indicate that the resistance cannot be so much in excess of that of a water-cooled engine of similar power. Further, it can be pointed out that the ABC Dragonfly engine has relatively high resistance for the power given, and that an engine of similar size and resistance with high-efficiency cylinders could be built to give 400 b.hp. at sea level. It would be of considerable interest if Messrs. Mead and Pierce would produce figures and the authority for their statements regarding relative resistance.

In view of the fact that the air-cooled engine has a considerably higher mean-temperature difference between the cooling surfaces and cooling air than the water-cooled engine, between 220 and 280 deg. fahr. mean temperature above air being an average figure for an air-cooled cylinder running with a blast velocity giving maximum power, the mean temperature depending upon cylinder size and the blast velocity varying from about 60 m.p.h. for a 65-cu. in. cylinder to 85 m.p.h. for a 150-cu. in. cylinder, and will therefore require less air to dissipate a similar amount of heat, it seems that there is a fair expectation that the resistance will therefore not greatly exceed that of a water-cooled engine faired with equal skill.

The statement that

> Air-cooling has advantages for an airplane, due to the tremendous differences in temperature under which the engines are forced to operate. It also makes the engine somewhat less vulnerable when used for military purposes. This does not seem to be a very important feature, since most planes that are shot down apparently fall because of fire rather than any other cause

does not agree with the views of many pilots who flew on the Western Front during the war. Many cases are on record of machines being brought down by a single shot through the radiator or a water-jacket. For instance, the engine from which the first official British published data on the 160-hp. Mercedes engine were obtained, was put out of action by a single shot through a water-jacket. Further, the connection between shots through the cooling system and the falling of the airplane in flames seems somewhat remote. The British, who used the stationary air-cooled engine to a greater extent than other belligerents in the great war, had a great respect for this type of engine on the score of reduced vulnerability.

A cylinder of 5⅞-in. bore by 6-in. stroke and of American design and manufacture, at 29.9-in. barometer and a 60-deg. fahr, air temperature, has given 120 lb. per sq. in. brake mean effective pressure at 1800 r.p.m., this cylinder being as yet relatively undeveloped. In view of the fact that few water-cooled engines of such size greatly exceed the above mentioned performance at such speed, it appears that fairly high mean effective pressures are not only a matter of report.

There is much doubt as to whether any real difficulty exists with reference to temperature control, provided the supply of heat to the induction system is such as to maintain reasonably constant carburetion and distribution. It is my experience, not alone with the aircraft engine, but with air-cooled engines generally, that it is possible to operate over a range of as much as 350-deg. fahr. variation in maximum cylinder temperature without any relatively large variation in engine performance.

While I am doubtful of expressing views on the matter of weight comparisons, as insufficient experience is at hand to make any sound conclusion, it does not seem fair to compare air-cooled engines operating on normal fuel and compression-ratios and a special water-cooled engine using a compression-ratio in excess of 6 to 1 and doped fuel, and further leaving the weight of the water and the radiator out of account. I refer to the statement that

> The V-type eight-cylinder engine is undoubtedly the lightest water-cooled engine known, for the reason that it has the shortest crankshaft for a given power. Weight factors of 1.45 lb. per hp. have been secured from this type of engine.

Mr. Vincent's statement to the effect that the radial form of engine was adopted on account of cooling difficulties, is not borne out by investigation. One 12-cylinder air-cooled V-type engine giving 220 hp., produced by the British in 1917 and subjected to severe experimental tests on the dynamometer and in the air, cooled as satisfactorily as any radial engine I have yet seen and, incidentally, much better than most water-cooled engines of similar power. The main disadvantage of the air-cooled V-type engine lies in the necessarily greater length compared with that of the water-cooled unit, due to the space required between cylinders. Experience in Europe has shown that the large V-type engine with 40-hp. cylinders does not have insurmountable cooling difficulties.

Comparatively little work has been done on the 9-cylinder single-row 300 to 400-hp. air-cooled radial engine, as no really satisfactory engine of this type has been produced. The mechanical difficulties of such an engine are not easy of solution and will need much careful work before the standard of maintenance and reliability set by the best water-cooled line or V-type engine is equalled. An engine of such power will have an approximate minimum overall diameter of 48 in., and the question of cowling and fairing for minimum resistance with good cooling will call for careful design and investigation. When experience is obtained by airplane and powerplant designers and test staffs, a considerable im-

provement on present fairing methods will no doubt be obtained rapidly. The problem can hardly be said to have begun to exist, as large air-cooled radial engines have not been used other than experimentally in small numbers. By enclosing and streamlining the valve gear and springs as far as possible, it is probable that a considerable reduction in the head resistance can be obtained; up to the present this feature has had little or no attention.

In the light of present-day knowledge it seems that if the air-cooled engine for military work is to compete with the water-cooled engine in the 400-hp. class, the only hope lies in the high-efficiency cylinder developing a mean effective pressure in excess of 130 lb. per sq. in. and using high compression. Experience has shown that a high mean effective pressure is necessary owing to the fact that the successful air-cooled cylinder has proved to be fairly heavy on a basis of weight per cubic inch of volume swept to weight. To design a cylinder of 150-cu. in. swept volume with a weight of 0.65 lb. per b.hp. requires considerable finesse.

The use of high compression has been shown to improve air-cooled performance, not only as regards the power developed and the fuel consumption, but the cooling efficiency as well; and, in this connection, the use of fuel dopes allowing of compression-ratios in excess of 6 to 1 gives promise of further improvement. On single-cylinder test engines, brake mean effective pressures of 135 lb. per sq. in. have been maintained regularly, but this is with lower blast velocities than are obtained under almost any flying condition in a pursuit machine. Such performance has been secured only under favorable conditions that would not exist in a multi-cylinder engine under service conditions, but this is likely to be balanced by the improved fuels for high compression and the eradication of faults that are shown in the cylinders while giving the performance mentioned. High performance from air-cooled cylinders is not obtained from the first casual idea produced on the drawing-board, or in the first run on the test block, but is the product of long and exacting test and design work. Owing to the wide variation in climatic conditions existing between the Mexican border and Alaska, it appears that the air-cooled engine has many advantages for military use in this Country. It would be unfortunate if the possibilities of the air-cooled engine were left untried owing to an attitude of mind that condemns without investigation and because all the problems have not been solved already. What would be the present state of aviation had the pioneers thought along such lines?

CHAIRMAN VINCENT: — I believe Mr. Heron's objection to my statement that air-cooled engines are made in the radial forms for cooling reasons rather than because of aircraft requirements is not really justifiable in the light of practical experience to date. Mr. Heron refers to the RAF-4A air-cooled V-type engine as an example of what can be done in constructing air-cooled engines in other than the radial or rotary form. According to the best information in my possession the engine weighed 4.17 lb. per b.hp., had a fuel consumption of 0.68 lb. per b.hp-hr., and an oil consumption of 0.067 lb. per b.hp-hr. While these figures undoubtedly can be, and probably have been, improved upon in other engines of this type, the horsepower-weight ratio and the economy figures given, as compared with water-cooled engines, leave much to be desired.

I wish to go on record as being a firm believer in the future of the air-cooled aircraft engine for certain purposes, and it is my conviction that the radial type offers the best field for development. I see nothing in the V-type air-cooled engine to commend it except a reduction of resistance, which in itself is open to question. The air-cooled radial engine has advantages in ease of cooling and mounting, accessibility, compactness and possibilities of weight reduction, that, to my mind, would more than offset any increase in resistance as compared with the V-type air-cooled engine.

I think, now as always, that air-cooled aircraft engines will be used extensively in the future and that, of the radial, rotary and V-type engines so far constructed, the radial engine has overwhelming advantages and deserves the greatest encouragement in development.

G. J. MEAD:—It seems that Mr. Heron's principal criticism was that we had overlooked the fact that much better air-cooled engines could be built. Apparently he did not understand one of the premises of the paper, namely, that it dealt with the actual performance of existing engines. I entirely agree with Mr. Heron that there is a possibility of considerable development of this type of engine. I will take up the points in the order in which they were discussed by Mr. Heron, with the hope that our ideas on the subject of the air-cooled type of engine will be set forth more clearly.

The statements regarding the parasitic resistance were based upon a mathematical consideration of a 375-hp. radial engine approximately 50 in. in diameter. The values derived were stated in Table 1 of our paper, as compared with those of a water-cooled V-type engine of similar power. The conclusion drawn from the figures was that an airplane with the air-cooled engine would have a loss in high speed of some 5 per cent compared with the same airplane with a water-cooled design. As Mr. Heron says, there are available no figures based on actual performance, at least not to our knowledge. It seems reasonable to suppose, however, that an engine with such a large frontal area would require more power for its propulsion through the air at a corresponding speed than another engine of equal power with less frontal area in the same plane. Engines smaller in diameter, 40 in. or under, will not be subject to this criticism, since they fair into the fuselage very nicely.

On the subject of vulnerability, the consensus of opinion of some of the pilots who were on the Western front seemed to be that more planes come down because of being set on fire than because of injury being done to their cooling systems.

We stated in the paper that relatively low mean effective pressures had been secured up to that time in this Country, which was correct at that time, I believe. We were not discussing the probable mean effective pressures that could be secured. The mean effective pressure of 120 lb. mentioned by Mr. Heron, was secured only very recently with a single experimental cylinder, I understand.

It is a more difficult problem mechanically to control the temperature of an air-cooled engine than of a water-cooled engine. This, I believe, will be granted. Whether it is necessary to provide temperature control, has yet to be proved.

Attention was drawn to the fact that, so far, air-cooled engines weigh very nearly the same per horsepower as the best water-cooled engines, complete with the water and the radiator. Mr. Heron makes the statement that successful air-cooled cylinders have proved to be fairly heavy. For that reason, it is necessary to increase the mean effective pressure to make these engines capable of competing with water-cooled engines in the 400-hp. class.

In conclusion, the whole radial air-cooled situation, as

I see it, is that the question whether large radial air-cooled engines are to supplant or compete with water-cooled engines, depends first upon developing cylinder constructions that will permit high mean effective pressures, and also the development of the mechanical parts of the engine so that they will be sufficiently durable for the service expected of them. I see no reason why air-cooled cylinders will not be developed that will give high mean effective pressures. Naturally, there is much careful experimental work to be done before the maximum efficiency of this type of cylinder can be obtained. Mr. Heron is doing some very conscientious work on this problem, and undoubtedly will be able to tell us in the near future of the cylinder limitations. In the meantime, development work must be carried on with the mechanical parts of the engine, including the crankcase, crankshaft, connecting-rods and valve-gear, since in this type of engine the designer is limited seriously by the inherent compactness of the type in securing the proper strength and accessibility, as well as durability, of its various parts. With the cylinder and crankcase assembly developed satisfactorily, we will be ready to determine the advantages of this type in flight, which will involve testing its ability to work under various conditions of temperature, the power available at different altitudes and the advantages in maneuverability due to the compactness. There is considerable scope regarding this whole problem, but I am glad to say that it is being attacked with enthusiasm by the Air Service and by individual engine designers in this Country.

CYLINDER ACTIONS IN GAS AND GASOLINE ENGINES

BY SIR DUGALD CLERK

THE distinguished author begins with a short account of the principal actions common to all internal-combustion engines and then proceeds to a more detailed account of the experiments that have been made to develop the theory and establish the properties of the flame working fluid of those engines.

The divisions of the paper are headed (*a*) short statement of cylinder actions, (*b*) the air standard, (*c*) flame the actual working fluid, (*d*) knocking, pinking and detonating, (*e*) air and exhaust supercompression, (*f*) residual turbulence, (*g*) gaseous explosions, (*h*) flame propagation and recompression, (*i*) the specific heat of flame, and (*j*) conclusions.

After treating (*a*) in considerable detail, the author discusses present efficiencies and knowledge in regard to the limits of the thermal efficiency possible in internal-combustion engines under (*b*), (*c*), (*d*) and (*e*), going into considerable detail and presenting and analyzing numerous diagrams and charts. Under (*f*) reference is made to the author's paper on the theory of the Gas Engine and the experiments of the late Professor Hopkinson are discussed. The subjects under (*g*), (*h*) and (*i*) are then elaborated upon, illustrated and described in a comprehensive manner, many data and analyses being presented in support of the author's thought. His conclusions refer directly to the cause of detonation and methods of preventing it. [Printed in the July, 1921, issue of THE JOURNAL]

THE DISCUSSION

D. ROESCH:—In summarizing, it seems that the following outstanding points are particularly worthy of consideration and discusson. The increase of flame propagation is a function of turbulence. More rapid flame propagation is in accordance with Beau de Rochas' principles and is basicly a desirable condition. In fact, high-speed engines would be impossible without this feature. With regard to turbulence from high inlet-velocities, from flame projection and from inherent combustion-chamber shapes, the final decision will be a compromise.

When inspection is made for possible gains, the air-standard efficency should not be used. The ideal efficiency should take note of the actual gases under consideration and also their specific heats at the various temperatures encountered. The difference in results obtained from those two methods is large. Another variable occurring at this point is that introduced by the maximum temperature obtained. This factor is of relatively small importance. Values of variable specific heats are available for this work. Profeshor Goodenough's book on Thermodynamics shows the method of making the computations. Because of the introduction of the variable specific-heat factor, the method involves a solution by trial and becomes laborious.

The introduction of air or cool exhaust-gases is suggested and urged. Considerable work along this line has been done. The methods of application may vary greatly. The one used by Sir Dugald Clerk is that of being under pressure at the end of the suction stroke. Another is that of being under atmospheric conditions at the beginning of the suction stroke. Observation of the action of such an engine in 1908 showed that, with air introduction in a scavenging-type engine, an actual mean effective pressure of 130 lb. per sq. in. was developed. For engines of this date, this was about 30 per cent above good practice and I believe represents high present-day values. This was a 19 x 25-in. engine operating at 175 r.p.m. on natural gas. Pure air was given a lead over the mixture and in this way permitted any degree of scavenging possible without danger of loss of mixture through the exhaust valve by over-scavenging. In the case of air or exhaust-gas introduction under pressure at the end of the suction stroke, attention must be given to the increased compression resulting from the higher initial pressure. In the case of carbon-dioxide introduction, dissociation is probably easier than in the case of steam or water introduction. The endothermic reaction resulting with carbon dioxide may be more available to reduce temperatures and favorably affect detonation troubles than is the case with water. However, the high nitrogen content must be considered.

The best method of analysis involves isolation of the contributing factors so far as possible. First, we can picture conditions by similes that more or less accurately represent the matter under investigation. For example, in the case of obtaining homogeneous mixtures, we know that, by volume, gasoline and air ratios are about 1 to 9000, while city gas and air mixtures may be to 1 to 6. An inherent handicap is placed on the gasoline engine. If one tries to mix a bottle of India drawing-ink with a tub of milk, one will have some difficulty in eliminating streaks. The streaks must be eliminated from the mixture of gasoline vapor, air and residual burned gases. The mixture can be pictured in the case of gasoline vapor and air as a flat sheet of absorbent cotton wet with aviation

gasoline. The sheet will burn comparatively fast. If we add some other materials to represent the residual burned gases, we can make the picture complete. Let us take asbestos wool wet with carbon tetrachloride for this substance and mix it in various ways with the highly inflammable gasoline-soaked cotton. By picturing the even distribution of the asbestos throughout the cotton we have ideal conditions, considering that the asbestos must be tolerated. Substantially uniform and maximum flame propagation results. With the asbestos unevenly distributed, the spark may occur in a relatively slow-burning section and get a bad start, or it may pass through a section of mixture rich in asbestos which slows up the flame propagation. The simile is useful in further exercising the imagination.

While these methods of inspection have their value in understanding matters better, definite exact inspections are more positive in the results attained. The laborious processes required sometimes delay and prevent their use. As an example, we find too little use of the temperature-volume and temperature-entropy diagram. Dr. Eddy gives a graphical method for transferring $p\ v$ diagrams in $t\ v$ and $t\ \phi$ diagrams.[2] However, the method uses constant values of specific heats, and if possible should be revised to care for the variable specific heats. This revision represents laborious work, but it is firmly believed that study along this line will pick out the details of heat interchange during compression, explosion and expansion, that will answer many of the questions now unanswered. The use of this method for a number of years as a collegiate thermodynamic exercise has demonstrated its value in imparting a better understanding of these rather intangible functions. Its value could be greatly augmented by the revision mentioned.

It would be well to emphasize that analyzing conditions at full load is only part of this work. Practically the entire discussion is for full-load conditions and we all know that efficiency ratios must be high for part as well as full load. In fact, the objection of high-powered engines being so wasteful could be overcome only by laying more stress on the light-load and low-compression conditions. A similar condition was present in the case of gasoline-consumption tests before the Society's recommended engine tests, for full, three-quarter, one-half and one-quarter load, came into extended use. The complete representation of the gasoline consumption for all loads and speeds can be represented by a surface. I described this method in a paper entitled Testing Variable-Speed Engines by a New Method.[3] This has proved to be a valuable means for showing the desired data concisely.

Similar means should prove equally valuable for comparing the relative merits along the lines of efficiency ratio and establishing standards of desirable performance.

MR. BREWER:—A period of great activity in research work upon the internal-combustion engine began in England in 1906 among several investigators. This included Professors Hopkinson, Watson, Burls, Callendar and Burstall, and other men in connection with the work of the Gaseous Explosions Committee. These men followed various lines of research and their findings are handed to us in the form of reports and papers presented before the several scientific institutions. They have established definite facts, from practical and scientific viewpoints, upon which all of the technical side of the automotive industry is based. The thermodynamics of the engine, including data relating to heat flow, temperature distribution and the specific heat of the fluid, were developed to a remarkable extent in the few years following. At the same time fuel and carburetion were investigated more seriously by myself and others. Sir Dugald Clerk took a very great and practical interest in all this work, and did much to assist the younger men, this attitude being typical of him.

At present, with the exception of the undertaking of one of the large oil companies, very little research work is going on in England, although further work is contemplated, and there is no doubt that Sir Dugald Clerk will be most interested in any work that may be done in America as a result of his paper. In 1906 he gave us a leader in his paper on Exhaust Gas Analysis as a means of determining engine performance. He said at the time that the results of analysis alone might be misleading, but that they must be interpreted in connection with the findings of other engineers and applied accordingly in order that the full benefit might be derived therefrom. Heat losses are not always of the magnitude originally conceived. For example, it has been proved definitely that the heat loss to a piston is only from 12 to 16 per cent of the total heat loss into the walls. This is much lower than is usually supposed, and the loss to the water-jacket is not due to direct radiation from the flame only at the time of combustion in the engine.

In his paper on the Limits of Thermal Efficiency, read before the Institution of Civil Engineers in 1907, Sir Dugald Clerk stated that the exhaust loss is under-estimated and the water-jacket loss is over-estimated because, when the exhaust-valve opens, the hot gases discharging around the valve impinge violently upon the water-jacketed metal in the valve-pocket before their direction is changed. In violent motion, these gases impinging against a metal surface lose their heat very readily, so that some heat which should appear in an exhaust-calorimeter reading appears in the water-jacket. There is an interesting fundamental feature in connection with thermal losses and this is the base H, which is the total loss of heat to the exhaust and the water-jacket in British thermal units per minute. All the heat losses and temperatures in the engine are correlated to this value, and Hopkinson shows his temperatures of various parts as a ratio to this value. Briefly, Hopkinson found in his series of experiments in 1907-1908 that the ratio of the temperature at the center of the piston to the value of H never greatly exceeded 0.200, that it was approximately 0.170 toward the side of the piston and that the fall of the temperature from the center of the piston to the water-jacket is proportional to the square of the distance from the center. About one-half of the temperature-drop occurs between the center of the piston and the oil-film, the remainder of the drop being between this film and the water. In no case is the inside wall of a cylinder at any temperature that is likely to be more than about 60 deg. cent. (140 deg. fahr.) above the temperature of the water. This is a point not always realized.

The heat loss from the underside of the piston also was determined to be between 2 and 3 per cent and the radiation from the top of the piston 12 to 16 per cent of the loss to the walls; so, it is evident that attempts to cool an engine by the circulation of air across the underside of the pistons can have only a small possibility of success. Experiments were made to determine the temperatures and conditions producing preignition. For this purpose a bolt 4 in. long was screwed into the exhaust-valve cover so as to project into the center of the compression

[2] *Transactions of the American Society of Mechanical Engineers*, vol. 21, p. 57.

[3] See TRANSACTIONS, vol. 12, part 1, p. 338.

space. After the engine was started, the temperature of the bolt would shortly attain a steady value, at which if not high enough to cause preignition, it would remain. A temperature of 700 deg. cent. (1292 deg. fahr.) could be maintained without apparent effect with ordinary mixture proportions; enrichment of the gas charge caused the temperature to rise farther, with the result that ignitions would begin and an abnormal rise in the temperature of the bolt would follow. At 710 deg. cent. (1310 deg. fahr.) the phenomenon would start and, when the temperature of the bolt reached 740 deg. cent. (1364 deg. fahr.), the effect was so severe that the engine would pull up. Some years previously Hopkinson showed that, when an explosive mixture is ignited from one point, the gas at the point of ignition is very much hotter than at a distant point. The reason for this is that the gas at the ignition point is first ignited almost at a constant pressure and is then compressed during the progress of the flame. The hottest place in the gas is at a small distance from the bolt. When oil was dropped onto the center of the exhaust valve, preignitions were produced when the temperature of the metal was as low as 450 deg. cent. (842 deg. fahr.), the ignition being due to the liberation of hydrogen as the fuel became split up. Ignitions may be caused by oil in this way, but they will be intermittent only.

Professor Hopkinson has stated that the investigations of Sir Dugald Clerk and others have proved that the work done by an engine developing 60 hp. could be increased only by one-eighth by conservation of the loss of heat and, further, that if the rate of heat-flow were known for every instant of time and for every point of the inner surface of an engine cylinder, it would be possible by a sufficiently elaborate mathematical analysis to determine the various temperatures inside the cylinder walls. Sir Dugald Clerk propounded what he termed his unit of heat loss as the cubic-foot degree, which is the amount of loss of heat in a cubic foot of mixture cooling through 1.0 deg. cent. (1.8 deg. fahr.), and he showed further that the loss of heat in an engine cylinder was 400 cu. ft. deg. per sec. per sq. ft. of surface.

Hopkinson analyzed these losses in an engine, the superficial area at the instroke being 2½ sq. ft. and at the outstroke 8 sq. ft. He showed that if all the heat were given to the surfaces of the piston and compression-chamber, the rate of heat-flow over these portions would be 640 B. t. u. per sq. ft. per min. as a superior limit and, taking an average area of 5 sq. ft., the rate of heat-flow in round numbers was 300 B. t. u. per sq. ft. per min. As an indication of the meaning of these figures, a bare steam-pipe at a temperature of 200 deg. cent. (392 deg. fahr.) loses heat by radiation and conduction at the rate of about 10 B. t. u. per sq. ft. per min. Considering the cylinder liner, the average rate of flow of heat through the metal will not exceed 600 B. t. u. per sq. ft. per min. and, to sustain this flow, a temperature gradient of about 60 deg. cent. (140 deg. fahr.) per in. of thickness is necessary, according to the experiments of Callendar and Nicolson on the thermal conductivity of cast iron. Thus, the inner surface of the cylinder liner can nowhere be more than 60 deg. cent. (140 deg. fahr.) hotter than the jacket water. Hence, the temperature is no higher than in the walls of a high-pressure steam engine.

Regarding the piston, the radiation considered as from a thin disc of radius a and thickness t, which is receiving heat at the rate H per unit area, is $ha^2/4kt$, where k is the thermal conductivity of the metal. If the heat-flow in the piston face is taken at 300 B. t. u. per sq. ft. per min., H will be 2.1 and k, according to the above authorities, is 0.064 at 180 deg. cent. (356 deg. fahr.), the other units being the inch, the British thermal unit, the minute and the centigrade degree. It is thus found that the temperature at the center of the piston will exceed that at the edge by 180 deg. cent. (356 deg. fahr.) approximately, when $a = 5.75$ and $t = 1.50$ in.

The heat given to the valve face is removed mainly by conduction along the stem and through the seat, and a sufficient fall of temperature must exist to cause this conduction. When a valve is coated with non-conducting material, the rate of heat reception will be nearly as fast as to clean metal, even though the temperature may be 300 or 400 deg. cent. (572 to 752 deg. fahr.) higher, so that a greater temperature gradient must exist accordingly.

The thermal calculations are all based on the value H, which is the total heat removed from the engine by the water-jacket and radiation in British thermal units per minute, and an average value of piston temperature gives the excess of center temperature over the mean jacket temperature of 300 deg. cent. (572 deg. fahr.) to 390 deg. cent. (734 deg. fahr.), the ratio of this temperature to the total heat, H, being between 0.207 and 0.198 respectively. At the edge of the piston the values of these ratios were between 0.175 and 0.164 respectively, and it was proved that these ratios were the same within probably 2 per cent whether the total loss was 1300 or 2000 B. t. u. per min. This proves that, within these limits, the proportion of heat received by the piston is substantially unaffected by the strength of the mixture. The highest recorded temperature at the center of the piston was 480 deg. cent. (896 deg. fahr.). It follows that the rate at which the heat is flowing into the piston face is 1.85 B. t. u. per sq. in. per min., when the total flow into the engine is 1600 B. t. u. per min., and this is the difference between the heat given by the gas to the metal and that lost by the metal by convection and radiation from the back of the piston.

To settle what the value of the radiation from the back of the piston would be, experiments were made which showed that, when the back was lagged, the temperature at the center was not more than 10 deg. cent. (18 deg. fahr.) higher with the lagging than without it. Not more than 2 or 3 per cent of the total heat received by the piston is lost from the back. The heat lost from the piston face was 12 per cent of the total heat-flow into the walls, compared with Professor Burstall's engine, which absorbed 16 per cent of the heat carried away by the cooling water. The proportion of heat received by the piston is considerably smaller than is imagined generally, as the area amounts to 30 per cent of the total exposed surface and it remains in contact with the hot gas during the whole stroke; even on the outer center it constitutes 11 per cent of the whole surface. This small absorption of heat is attributable only partly to relatively high temperature, for the excess of the temperature of the piston over that of the other parts of the engine, although considerable, is still a small fraction of the difference between the mean temperature of the gas and that of the metal. Probably a heat loss of 300 B. t. u. per min. occurs during the time when the hot gases rush past the exhaust-valve at the moment of release. Practically the whole of this loss goes to the valve and passages and none to the piston.

In regard to the exhaust valve, with a rich mixture the mean value of the relation of the temperature to H was 0.217; with a lean mixture it was 0.240. In the inlet-valve, with a rich mixture this value was 0.127; with a lean mixture, it was 0.134. Under ordinary conditions

the temperature at the center of the exhaust valve was 400 deg. cent. (752 deg. fahr.); at the inlet valve, it was 250 deg. cent. (482 deg. fahr.). There was a decided decrease, 10 per cent, in the ratio of the temperature of the exhaust-valve to H when the strength of the mixture was increased, the explanation being that the heat loss occurring during the outflow of the exhaust gas just after release goes mainly to the valve, and that this part of the heat is not much less in absolute amount with a weak than with a strong mixture. The temperature does not diminish in proportion to the heat supply, because there is a small percentage of heat loss with the weaker mixture, more going into the exhaust. Thus, the loss to the exhaust-valve in this way forms a greater proportion to the whole loss when the mixture is weak. The temperature of metal at any point is determined by the rate at which the heat passes into the surface per unit area and the distance that the heat must travel to the place where it is removed. In geometrically similar engines of different sizes, the distribution of temperature will be similar, but the temperature at corresponding points will be approximately proportional to the linear dimensions; that is, if the thickness of the piston face is halved, the fall of the temperature from the center to the edge would be doubled approximately and preignition probably would occur with heavy charges.

H. L. HORNING:—Mr. Brewer referred to the area between the valve-pocket and the cylinder proper. That is very important. The gas must be put through a very narrow passage to maintain velocity.

I recommend the reading of a paper by W. A. Tookey, an Englishman, on the Testing of Gas Engines. He brings out fundamentals of great importance. I think Professor Dixon's work also is excellent. I advise that Ricardo's recent articles in the *Automobile Engineer* be studied. They are fundamentally correct, as are the articles by Tizard and Pye on the Changes in Specific Heat. There is nothing better in all the literature on the subject. Ricardo has fallen into an error in his chemistry, however, in that he uses very impure hexane and heptane of vegetable origin in his research, getting vastly different characteristics from those two closely related paraffins that are alike in structure and of nearly the same molecular weight.

SIR DUGALD CLERK:—I take much pleasure in thanking Professor Roesch for his careful and appreciative summary of my paper. There are very few points that I desire to mention further. The air standard has proved very useful in providing a definite means of comparison for engines using varied compression-ratios and shapes of combustion space. It enables us to establish a figure of merit; that is, a value for the efficiency ratio as between the results actually obtained from a particular internal-combustion engine and those that could have been obtained had the working fluid been pure air and no heat or other loss been incurred to the cylinder from the enclosed hot air.

In my Royal Society paper of 1906 and Institution of Civil Engineers paper of 1907 I established the ratio 0.65 as that given by the best engines of that time and I pointed out that using actual specific-heat properties of a coal gas and air working fluid, the actual working fluid ideal efficiencies should be broadly 20 per cent less than air-standard values. I also pointed out that for all ordinary coal-gas engines the actual working fluid values could be easily obtained by using a gamma value of 1.285 instead of that of 1.400 of the air standard.

The efficiency formula has then an exponent 0.285 instead of 0.400 and the actual working fluid consisting of nitrogen, carbonic acid, steam and some excess of oxygen, gives efficiencies E for varying compressions.

$$E = 1 - (1 \div r)^{\gamma}$$

For compression-ratios of 3, 4, 5, 6 and 7 the ideal efficiencies of the actual working fluid are very nearly as given in Table 1.

TABLE 1—APPROXIMATE IDEAL EFFICIENCIES OF ACTUAL WORKING FLUID

$1 \div r$	3	4	5	6	7
	0.269	0.326	0.368	0.400	0.426

Prof. H. L. Callendar arrives at the same value of γ by a different method as mentioned by him in the discussion of the 1907 paper. This takes note of the change of specific heat with temperature without requiring the use of the laborious method of successive approximations.

I have used varied methods of introducing cool exhaust and in the large engines of the National Gas Engine Co. I have caused the exhaust gases to be drawn into the cylinder with the charge. The method of adding under pressure is adopted only when it is desired to obtain the higher mean pressures due to super-compression. I am in full agreement with Professor Roesch as to the necessity of considering light-load conditions down to one-quarter load and even lower. There is still much room for the investigation of light-load efficiencies.

I have not mentioned exhaust-gas analysis in the paper but I fully agree with Mr. Brewer as to the substantial help to be obtained by the practice of such analysis. I presented a paper entitled The Principles of Carbureting as Determined by Exhaust-Gas Analysis, to the Institution of Automobile Engineers in December, 1907.[3] This followed tests made at a Royal Automobile Club trial of 12 cars under ordinary conditions of running on the road. The method has been used ever since that trial. Mr. Brewer also alludes to my investigation of the effects of suction turbulence, now generally acknowledged as of vital importance in the action of the gasoline engine. I agree with Mr. Brewer's summary of the work of the British Association Gaseous Explosions Committee, of which I am chairman.

I thoroughly agree with Mr. Horning's remarks on the importance of Mr. Tookey's work on gas engines. Mr. Ricardo's work also is of great importance. I shall watch with interest the experimental work of the younger American engineers, whose investigations appear to me important and ingenious.

TURBULENCE

BY H. L. HORNING

THIS paper is a [illegible] of notes gathered from investigation of the subject in the literature on the development of internal-combustion engines and memoranda set down during a long series of tests. The paper includes a discussion of the physical and chemical aspects of the subject and sets forth a working theory that has proved of value. Several methods of measuring turbulence are stated.

After outlining the history of the subject and giving references, the effect of turbulence on flame propaga-

[illegible]

tion is discussed at length and illustrated by diagrams. Two methods of producing turbulence are then copiously illustrated and described, inclusive of seven diagrams showing characteristic turbulence in typical cylinders.

Following the description of the methods of measuring turbulence, the effects of turbulence in performance are summarized under 10 specific divisions. [Printed in the June, 1921, issue of THE JOURNAL]

THE DISCUSSION

H. M. CRANE:—We built an L-head engine and a valve-in-head engine of practically identical characteristics. As to power, the actual results in service were almost identical. We obtained a slightly higher mean effective pressure from the valve-in-head engine. We designed it originally with a 25-deg. spark-advance. In the first test we could get no power and it sounded like a two-cycle motorboat engine. We know now that this was due to the after-burning in the exhaust. The final result in that engine was that we required from 60 to 65-deg. spark-advance to maintain the maximum power at the peak of the power curve, at 2500 r.p.m.

The equivalent L-head engine gave the same results with only a 25-deg. spark-advance. Fortunately, we were able to add a second spark-plug to the valve-in-head engine. The spark-plugs were diametrically opposite each other; we put in two at right angles to the center-line of the valves. With the two spark-plugs we were able to reduce the maximum spark-advance to 30 or 35 deg. The engine ran considerably more smoothly with the two spark-plugs than with single spark-plugs. In idling we found another extremely interesting condition. With two spark-plugs and a careful idling adjustment, we would get a certain result. If we cut out either set of spark-plugs, it was necessary to enrich the mixture nearly 25 per cent to get the engine to idle. Of course, that is due to the fact that it is a low-turbulence engine in every respect; at idling speed there is practically no motion in the mixture. On account of the form of combustion-chamber there is no segregation of mixture such as obtains in an L-head engine. Occasionally we would get a burnable mixture and at the next attempt we would not; the engine simply would not operate satisfactorily. The weakness of the low turbulence and big spark-advance lies in the fact that the engine is igniting at a very low compression. That is the unforunate part of it. With a 65-deg. spark-advance on an engine of any normal proportions we are not nearly utilizing the compression that we are supposed to be realizing; the engine is actually still compressing after ignition. I think that is bound to affect the results adversely. The advantage of the overhead-valve engine is that it has a much better shaped combustion-chamber. In our experience with respect to detonation the improvement in the shape of the combustion-chamber over that of the L-head engine, which is not very good in that regard, was sufficient to obliterate entirely the difference in the turbulence. that is, granting that the turbulence was far greater in the L-head engine, which I am sure it was.

Those tests show that the turbulence we can do real business with is that produced during the compression stroke. that is, the turbulence produced during the inlet stroke in an ordinary engine dies away, in the overhead-valve engine especially. As to the direction of turbulence in the overhead-valve engine, I think that Fig. 8 of Mr. Horning's paper is not exactly a true representation of all cases. For instance, an engine with the valves in the longitudinal center-line of the engine has the inlet pipe at right angles to the longitudinal center-line; the mixture enters the port on a distinctly tangential line, and I think that in no ordinary design of engine the streamline in the valve-port is sufficient to straighten out the turbulence. In other words, there is a whirling turbulence, such as it is, in that type of engine; it will not be a perfectly vertical turbulence as if the mixture came in straight as in Fig. 8 of Mr. Horning's paper, and one must bear that in mind when searching for the spark-plug position because, undoubtedly, it has a bearing on it. We are now working on an overhead-valve engine with four spark-plug locations available, and will be able to explore and see what result we can get.

Another confirmation of Mr. Horning's statement regarding the detonation in the L-head engine is that in a number of engines of ours that were rather bad on detonation in certain ways, a tremendous improvement was brought about by using aluminum pistons. The result was that we removed the hot-spot that was farthest from the spark-plug, the spark-plug being located normally over the inlet port; the engines are of the L-head type. I have tried the spark-plug over the exhaust port and I think there was a slight advantage. The two valves were so close together that it would take a trained observer to decide that there was any difference. There is no question that there is a difference between using an aluminum and a cast-iron piston. In the overhead-valve engine, especially when using two-point ignition, I doubt whether there is any very noticeable difference between aluminum and cast-iron pistons. We certainly did not notice any in the tests that we made. In other words, the more we work on this subject, the more we will find that we are converging on a given point of knowledge that will be fairly definite; but, unfortunately, it is almost impossible to combine violent turbulence with a very good form of combustion-chamber; so we must bear in mind that we are working with compromises all the time, and that we cannot say now that an L-head engine is the only one to use because we can get a very high turbulence with it, any more than we can say that an overhead-valve engine is the only thing to use.

PROF. ROBERT E. WILSON:—I think there can be no doubt about the essential validity of Mr. Horning's conclusions as to the value of turbulence. However, in the explanation that he offered for this result, he assumes that turbulence increases the number of collisions between the reacting molecules and thereby increases the rate of reaction. I believe that this cannot be substantiated; to illustrate why, assume that all the people in a room are moving about violently; the number of collisions that they have with one another will be determined by the number of people in the room and by the rate at which they are moving. Merely superposing on this rapid vibratory motion a mass-motion of the room as a whole in a single direction will not affect the result in the slightest. The fact that the earth is rotating and that we are all going forward at enormous speed has no influence on the number of collisions that would happen in this supposed room. It is the same with the molecules. They are moving back and forth at enormous velocity. Simply superposing a comparatively slow mass-motion would have no effect, because 500 ft. per sec. is nothing at all compared to the molecular speed of vibration. Of course, if one side of this room I mention were moving much faster than the other, it might increase the number of collisions, but even that factor could not enter, in Mr. Horning's case, because the rate of motion is very small compared with the rate of molecular vibration.

I think Mr. Horning's other suggestion with regard to eliminating dead pockets and such effects is much more likely to be the explanation of the value of turbulence.

May not the localized deposition of carbon that Mr. Horning mentions be due to the burning off of the carbon from the hottest part of the pistons?

W. S. JAMES:—The presence of exhaust gas in the explosive mixture has a marked effect on the leanest mixture on which an engine can operate. We have found that, as the throttle-opening is decreased, the engine cannot run with as lean a mixture as at full-throttle. Why is this? At the end of an exhaust stroke, regardless of the load on the engine, there is a practically constant weight of exhaust gas in the clearance space. This weight may vary slightly with the exhaust temperature, but is otherwise independent of engine speed or load. If the turbulence of the cylinder charge is increased, the exhaust gas mixes with the incoming charge and reduces its inflammability. The result is that we cannot fire as lean a mixture as we can when we have a completely fresh charge. It seems to me, therefore, that turbulence is good as long as we can control it, but this is probably difficult to accomplish. In an engine cylinder, if we can stir the fresh incoming charge and still keep it separate from the exhaust gases, we will have effective turbulence. If, however, we mix the fresh charge with the exhaust very thoroughly by turbulence, we will lose in maximum economy. This fact may be overlooked, as it is so well known that exhaust gases exist that we forget about their presence.

In the derivation of the expression for air-cycle efficiency as given in the classical works, we find that about eight assumptions are made. At least five of them are included among the factors that Mr. Horning has grouped in his expression for combustion efficency. After considering the derivation of air-cycle efficiency and the assumptions made, we realize that air-cycle efficiency is the efficiency of expansion and nothing more. It is the efficiency of the expansion ratio; all the other factors involved in combustion and the faults of fuels and fuel mixtures as they exist are assumed to be zero. When we talk about air-cycle efficiency, let us remember that it is simply the completeness of expansion. If we know the other factors, such as the variation of specific heat with temperature and pressure, the difference between the ratio of specific heats on the expansion and compression strokes and the fact that a fuel mixture does not burn instantaneously at the time of ignition, let us blame them on the fuel and not on the engine cycle.

H. C. GIBSON:—I agree with Mr. Horning that turbulence aids wet mixtures. A Knight engine is one of the best instruments for the production of turbulence. The intake gases rushing along into the cylinder have an absolutely clear passageway thereinto; there is nothing to obstruct them in the slightest degree or to reduce their speed. Their plane of entrance to the cylinder permits them to continue the motion in a whirling manner within the cylinder. The consequence is that they come to a condition within the cylinder after the closure of the port where their original speed can be maintained more readily. It is easy to understand that, with this form of engine, we can have far greater turbulence than with any form of engine using valves; and Knight-engine turbulence will maintain itself for a longer period. Residual exhaust gases exist and their proportion is greater in ordinary use the more the throttle is closed but, to have an engine operate satisfactorily to the customer, irrespective of the number of miles attained per gallon of fuel, every cylinder must fire regularly. With wet mixtures, the greater the turbulence one can attain in the cylinders under throttled conditions, the more certain the firing of the charge will be, but throttling is the very worst condition for obtaining turbulence in the cylinder because the major turbulence occurs at the throttle. By using really evaporated fuel we can mix the active charge thoroughly with the exhaust gases and produce approximately the same conditions in each cylinder of the engine better than we can with the poppet-valve type of engine, and the loss of turbulence after the gases pass the throttle is no detriment.

W. G. GERNANDT:—Is the increased efficiency of this type of combustion-chamber due to turbulence rather than to localizing the mixture where the flame propagates for the least distance?

MR. HORNING:—Mr. Crane's remarks to the effect that the representation in Fig. 8 of my paper of the turbulence in an overhead engine is not a true representation of all cases for that type of engine, are correct. Each engine has its peculiarities. Fig. 8 shows what we could deduce from the knowledge of the following governing factors: (*a*) location of intake; (*b*) direction of gases entering cylinder; (*c*) shape of top of chamber; and (*d*) the direction of the gas currents at the time of ignition as deduced from the engine performance with the spark-plug in various places.

Professor Wilson's remarks regarding my explanation of why turbulence causes increased flame propagation are pertinent. I did not wish to convey the idea that more contacts are made between the molecules in a given time because of turbulence. The thought I desired to express is that when the mixture is circulating at a high velocity past the spark-plug at the instant of ignition, small reaction or combustion nuclei are scattered in great numbers throughout the mixture, approximating the effect of a vast number of spark-plugs. The chances of such contacts in a given time are greatly increased where turbulence increases the number of initial reaction points.

Mr. James' figures as to the number of contacts and molecular characteristics are very interesting and his remarks regarding the effects of exhaust gases, known sometimes as residual products of combustion, are to the point. I agree fully with his view as to the effect of the relatively greater proportion of inert gases by weight as the load decreases. If the products of combustion could be kept quiescent and segregated while the combustible mixture was turbulent at the time of the spark, the process would be carried out with great efficiency. This contention of Mr. James is correct. There is a point of practical interest that adds great value to his suggestion, namely the question of the leanest mixture that can be burned is decided by the leanest mixture that can be ignited; a distinction of great importance. It is known that after ignition is well started in a rich mixture, it will propagate down into a mixture so low in fuel value that great performances in economy can be obtained experimentally by following this order of operation. It can, therefore, be said that after a certain proportion of the total combustible charge has been ignited, and a certain temperature or pressure reached by the explosion, it is immaterial whether there is complete, practical or partial segregation of the inert gases and it is relatively unimportant whether there is turbulences of the whole mixture or not. This fact may be of great value in putting into practice what Mr. James has so clearly pointed out.

Coming from so careful a student as Mr. James, the remarks regarding air-cycle efficiency are very interesting and a full understanding of them will no doubt bring about clearer thinking. There is no place where I have, to my knowledge, assigned to the air-cycle efficiency any other value than that arising from the expansion ratio. Mr. James has twice stated in his remarks that "air-

cycle efficiency is expansion ratio." I cannot help but feel that what he desired to state is that air-cycle efficiency is the efficiency arising from the expansion ratio of ideal air or working fluid whose specific heats do not change with temperature and the ratio Υ of the specific heats

$$C_p/C_v = \Upsilon = 1.408$$

Tizard and Pye have called attention to the other ideal features of the cycle which is shown at the left of Fig. 14. These features are

(1) Compressed adiabatically in the ratio $V_a/V_b = \Upsilon$
(2) Instantaneously heated at the constant volume $V_b = V_c$ to its maximum temperature of t_c deg. cent.
(3) Expanded adiabatically to its original volume $V_d = V_a$
(4) Cooled instantaneously at a constant volume to its original temperature t_a deg. cent.

It will be noted that it is impossible to ever attain practical operation and have conditions which line up with these assumptions listed below.

(1) The working fluid does not have a constant ratio of specific heats at all temperatures
(2) The working fluid does not have a ratio exactly like that of ideal air
(3) It is impossible to compress adiabatically
(4) It is impossible to release the spark at the end of the stroke and it is impossible to add heat instantaneously at constant volume due to the slow burning of the mixture
(5) There is always dissociation of the products of combustion and some after-burning at the peak of the diagram which upsets the form at the peak and it is rare that we have a point c
(6) It is only approximately possible to expand a charge adiabatically, there being a considerable loss of heat during the first twentieth part of the stroke due to high temperatures
(7) It is impossible to lose heat from the point d to the point a instantaneously and the general form of the diagram at the top must be rounded off so as to exhaust early to get a complete exhaust
(8) The volume of the products of combustion of the usual gaseous fuels is less than the original fuels at the same temperature and pressure, while with gasoline and the liquid fuels it is more
(9) As a matter of fact, a loss due to radiated heat occurs throughout the cycle, which is not assumed in the cycle

These practical deviations from the assumption of the engine working on ideal air and the actual working fluid together with the other deviations listed above result in gains and losses from the performance to be expected. This causes a distinct loss, which, as outlined in Sir Dugald Clerk's paper, is between 30 and 40 per cent of the air-cycle efficiency. This loss is expressed as relative efficiency and this relative efficiency goes up and down according to the efficiency with which the mixture is burned. In an investigation in which the only changes in the factors are those affecting turbulence, since the net results of these changes are recorded in the performance through the ratio of the indicated thermal efficiency to the air-cycle efficiency, we have in this a valuable index to the value of any design with reference to turbulence. Referring to Mr. James' remarks on the matter analyzing the factors that make the loss accounted for in relative efficiency, I admit it takes a great amount of clear thinking to assign values based on the available data. However, I shall be glad to have Mr. James point out any de-

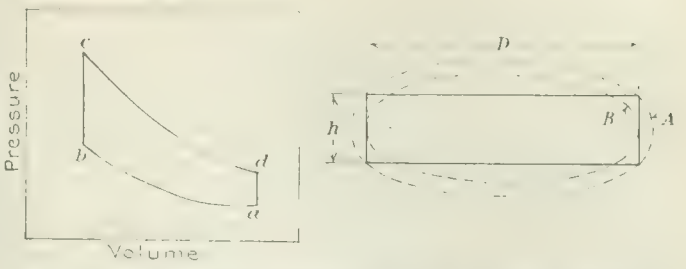


FIG. 4—AN INTERNAL-COMBUSTION ENGINE CYCLE HAVING A NUMBER OF IDEAL FEATURES AT THE LEFT AND AT THE RIGHT A DIAGRAM SHOWING HOW IT IS POSSIBLE TO INCREASE THE VOLUME OF A CYLINDRICAL CROSS-SECTION VERY MATERIALLY WHILE ONLY CHANGING THE AREA SLIGHTLY

fects that have crept into my paper or the above presented view.

As to his remarks regarding the number of molecular contacts in a second, I would state that initiating the flame at a great number of points gives the particles of gas a chance to distribute the flame quickly through the mixture by utilizing the kinetic properties of the gas to the best advantage.

I can confirm Sir Dugald Clerk's paper and the discovery of Prof. Bertram Hopkinson that the spark-plug is the hottest point in the cylinder, due to adiabatic compression.

Concerning Mr. Gibson's remarks on the Knight engine, I would say that I have been driving a Knight engine and want to confirm the statement that it is very efficient from a turbulence standpoint. Whether this is the cause of the very slight tendency to knock or whether a low compression-ratio is the cause, I do not know. On page 446 of the May 1921 issue of THE JOURNAL will be found results of tests made by me on a Knight engine. It is obvious that it would be disappointing to find a knock in an engine with so low a mean effective pressure. There is no doubt that turbulence was responsible for the excellent indicated thermal efficiency and the mechanical efficiency was remarkably fine for a stock engine.

The point Mr. Gernandt brought up is excellent. There is no doubt that the hemispherical combustion-chamber shown in Fig. 7 of my paper is a very good one from the standpoints that it is compact and has the spark-plug in a position so favorable that the distance is relatively short to all parts of the mixture. The flat section above the piston is very bad for detonation. It is interesting, however, to know that the mean effective pressure developed is to the mean effective pressure that could be developed by the energy contained in the total volume, as the volume of the hemispherical part is to the total volume of the combustion-chamber. In other words, the flat part enters into the combustion too late to contribute to the mean effective pressure.

One of the fundamentals in a combustion-chamber, as pointed out some years ago by L. H. Pomeroy, is, of course, the desirability of having as small a volume as possible of stagnant gas lying against the wall of the combustion-chamber. It seems impossible to determine the thickness of the inert layer and so we are only permitted through turbulence to drive the layer off into the burning sections. We can, however, try to keep the area with relation to the volume down to the lowest minimum. It is interesting to note the following methods of doing this. If we have a cylindrical cross-section, such as is shown at the right of Fig. 4, having a diameter D and height h, it is possible to increase the volume considerably while increasing the area only slightly by giving the chamber the ellipsoidal form shown by the bulging dotted lines A or B. This is the first step in an evolution

ending in a perfect sphere. The ellipsoid is next to the hemisphere in favorable ratio between volume and surface.

Mr. Pomeroy kindly called my attention to a paper presented by him in 1919 before the Institution of Automobile Engineers of Great Britain, in which he sets forth conclusions regarding the influence of engine speed on turbulence. I have studied it with great interest. Mr. Ricardo has made an analysis of the results shown and indicates pretty conclusively that gas velocity is of primary importance in the matter of determining the speeds at which the best performance can be expected. Numerous tests seem to show that it must be considered a first approximation inasmuch as the gas velocities at which the maximum brake mean effective pressures occur vary from the wide limits of 120 to 175 ft. per sec. It appears as a general rule that where it is desirable to attain very high values for the brake mean effective pressure and indicated thermal efficiency at speeds below 1000 r.p.m., the higher gas velocities will be necessary, that is to say, approaching the 170-ft. per sec. valve velocities. In engines where it is desirable to have maximum brake mean effective pressure and maximum thermal efficiency at speeds of 1800 to 2000 r.p.m., it is generally to be expected that gas velocities of the lower value obtain, at these speeds of from 120 to 150 r.p.m. The product of the gas velocities and the engine speed seems to tend to increase, roughly, at a less rate than the engine speed.

MR. BREWER:—We have supposed for a long time that combustion is complete at about one-tenth of the downward stroke of the piston in the cylinder bore; it should be, but it is not. What we are trying to do by turbulence and by other means is to obtain that completeness of combustion in that small interval of time. However, we know that, under certain conditions, the combustion is carried on to a later stage in the cycle of operations of the engine, and we suffer therefrom. We are trying to find why the combustion is delayed and exactly what effect the heat of delayed combustion is having upon the engine. The whole question hinges to a very considerable extent upon the source of the generation of heat, and upon the heat-flow from the time of maximum temperature.

To amplify what Mr. Horning said with regard to the generation of heat from one single point, I would point out that it was discovered by Professor Hopkinson that if an artificial heated surface were produced in the engine, which he accomplished by using a bolt fixed inside the combustion-chamber head, certain conditions would arise with regard to the temperature of the head of that bolt as the mixture strength was increased. With the normal mixture strength, when a temperature of 700 deg. cent. (1292 deg. fahr.) was reached in the bolt-head, the condition of stability was reached. When he enriched the mixture beyond that point, even though it were only about 1 per cent, ignition would start from the vicinity of the bolt-head and, as soon as ignition started from the vicinity of the heated surface, the rise of temperature of the heated point was exactly 10 times as rapid as it was before. In other words, in rising from 640 deg. cent. (1184 deg. fahr.) the temperature of the head had a certain definite increase in temperature rate amounting to 2.5 deg. cent. (4.5 deg. fahr.) per explosion, but as soon as the firing started from the neighborhood of this spot, the rate of temperature increase was 10 times as fast, until the engine refused to work. This shows that high temperatures are being generated from the source of ignition. Professor Hopkinson was definitely satisfied that ignition was not occurring from the metal of the heated surface, but only from the neighborhood of the metal. He showed further that when that heated metal was coated with carbon or any other material of a non-conducting character, this did not materially affect the phenomenon of heat being started from the hot zone.

G. P. DORRIS:—A possibility which I believe has not been mentioned is that in the combustion of the gas, as explained by Mr. Horning, the pressure is applied to the piston from two sources. There is first an expansion pressure due to the heat that drives the piston, but there is also the secondary force of the velocity of the gas being thrown against the piston. We can slide tons of airplanes on the air, which shows that the air is of a very definite weight. This combustion matter also is of some definite weight. If the rate of combustion is as fast as sound, as I understand has been stated, it is possible that, with Mr. Horning's combustion-chamber, he fires the mixture in a comparatively segregated combustion-chamber, from which it is blown into the main combustion-chamber with such velocity that the pressure is distributed more uniformly during the working stroke, therefore preventing the possible detonation and the knock that we have been discussing.

ELIMINATING CRANKCASE DILUTION BY MANIFOLD DEVELOPMENT

BY G. P. DORRIS

ABOUT 1917 the heavy ends of the fuel sold as gasoline required such an amount of heat to vaporize them that the expression "crankcase dilution" appeared; now they have increased to a maximum boiling-point of 446 deg. fahr., which has made it necessary to go still farther in the direction of heat application.

After a brief consideration of the relative heat-absorption of air and fuel and the time factor in its relation to vaporizing, the author describes experiments with a specially designed manifold for increased vaporization efficiency and presents photographs of the device.

With this type of manifold it has been possible to eliminate crankcase oil dilution completely and effect a reduction in carbonization. The lubrication efficiency has been improved, as well as other features that are enumerated. [Printed in the July, 1921, issue of THE JOURNAL]

THE DISCUSSION

MR. DORRIS:—In the new pipe, shown in Fig. 1 of my paper, the two center pockets are exhaust pockets that lead out to the side and down to the exhaust pipe. This was certain to throw the heavy ends against the hot wall and gasify as much of the fuel as possible at that point. The engine operated very well on the lighter gasoline, but we found that the four center cylinders were very much favored and that the two end cylinders were inclined to foul the spark-plugs and prevent operation.

We have had any number of cases where cars operated very satisfactorily until they got a dose of heavy ends from some gasoline station. It has required considerable effort to explain to the public why this is and to put the blame on the fuel and not on the engine. That has been one of the conditions that prompted us to continue this change to prevent liquid fuel from entering the cylinders. The bottles shown are 4-oz. sample bottles that we fill about one-half full when starting. This is a fairly crude arrangement, and it by no means collects all the fuel that trails into the two end cylinders. Since we installed this new pipe, we have noticed a material improvement in uniform distribution and it has actually quieted the engine considerably on account of the uniformity of performance of the different cylinders. We formerly used hot air with this arrangement, but on the new arrangement hot air is eliminated entirely.

Fig. 2 of my paper shows the first pipe we made after this change. The heater was put on to control the excessive heat. The gas was fed into the side of the pipe and passed through the top down into the different cylinders. The two pipes being cast together, the temperatures ran fairly high. The engine operated very clean and very sharp; in fact, there was very little drag to it but it was not fully up to its efficiency on account of the reduced compression. These bottles were installed to get a relative idea of the amount of gas passed over to each cylinder so that, if possible, we could arrange the pipe in such a way that it would make that as uniform as it could be made. That led us to tap the heavy ends back to the central pocket, so that it automatically boils them out and sends them over as vapor.

In the revised pipe shown in Fig. 3 of my paper, the exhaust is separated from the overhead admission pipe. It has sharp bends, where the velocity effect of throwing the gas over drops some of it into the cylinders and distributes those heavy ends; so that has its effect in uniform distribution. The large heater shown was installed temporarily to get some idea of the amount of heat required.

The final pipe, shown in section in Fig. 4 of my paper, leads the gas up into the carbureter through a heater that is controlled by checking the supply and outlet at exhaust atmospheric pressure. This gas is thrown over against a blind wall, so that it is not swept on over to the cylinder but is given an opportunity to drop the heavy fuel in the pocket between this exhaust pipe and a similar pipe on the opposite side. That provides an excellent still, a heating apparatus in which to vaporize this fuel.

The one fact that we have overlooked is the time element required to vaporize this heavy oil. Formerly it has been shot through at such a rate of speed that we about burned the skin off of each ball of gasoline and shot the core out at the exhaust pipe. After we had gotten this pipe into operation and had settled on a production pipe, we put in 1 gal. of kerosene to test the relative capacity of vaporizing even kerosene. I believe this test, resulting in our obtaining 17.1 miles on that quantity of kerosene, assures us that practically none of it was passed over to the engine cylinders. On this test that was not by any means the maximum that could have been obtained. It was simply run as a comparison to get some idea as to how the different fuels perform under identical conditions.

This whole procedure has unfolded many possibilities for further experiment that we have not as yet had time to continue, in seeing how far we can go with a cross between kerosene and gasoline and as to what troubles develop in a trend toward a kerosene engine. This will

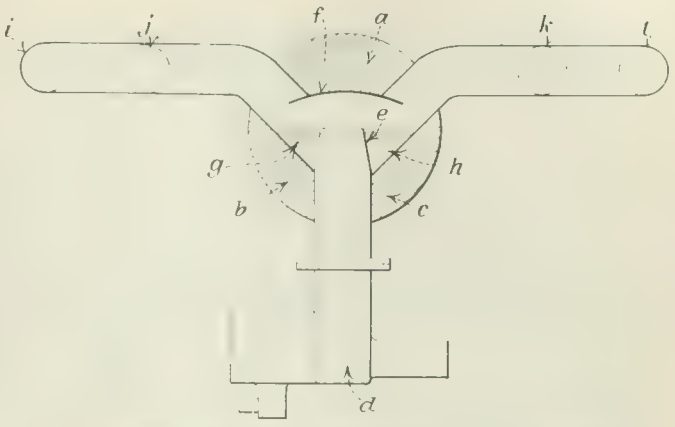


Fig. 5.—Special Manifold Developed for Burning Kerosene

be followed up immediately, but the results so far gained have been so gratifying that it is safe to state that we have improved the efficiency of our engines at least 10 per cent and they are absolutely free from crankcase dilution. In line with this and in regard to the two end spark-plugs that were fouling considerably and constantly, it is possible now to put in greased plugs and burn them clean, which seems to reverse the condition that we had formerly.

A. W. Scarratt:—Fig. 5 is a sketch of an intake manifold that is burning kerosene, built on the same principle as the one described by Mr. Dorris. I showed this sketch a year ago at the Ottawa Beach Semi-Annual Meeting. The exhaust comes through the three areas *a*, *b* and *c*. The carbureter hangs down below, at *d*. In this manifold we get the maximum velocity at the end of the vertical intake-pipe, or nozzle, *e*. The gas in coming through the nozzle, due to its velocity, impinges against a sort of hemispherical or umbrella-shaped dome at *f*, that is a highly heated surface; it then travels under the edges of the dome and into the airstream. In making development experiments on this manifold we tapped into the basins *g h* to see how much of the heavy ends we could collect at those places. This is essentially just what Mr. Dorris did. The heavy ends do roll back on the manifold walls and gather in the pockets at *g* and *h* that are out of the main airstream and consequently in a slight vacuum. This manifold was developed for use on a 16-valve truck engine that we build, to improve the operation on gasoline. We had no idea at the time of using it for kerosene and, after experimenting in choosing the right size of manifold, we found that with a 155-deg. fahr. temperature at the intake ports at *i*, *j k* and *l* we obtained exactly the operation that we desired on gasoline. Through curiosity, we tried the same manifold on kerosene with the result that, without any change whatever, our temperatures on kerosene rose 30 deg. higher, or to 185 deg. fahr. at which heat we had complete vaporization. We made the outer arms of the manifold of glass so that we could actually see what was taking place in it. The manifold is standard on our truck engines at present, and will become standard equipment on our tractor models eventually. We have two 3½-ton trucks of very liberal dimensions throughout in operation with this manifold, using kerosene as fuel, and have had them in service all this past winter. In using gasoline throughout the winter, we were fortunate if we could obtain from 3 to 3½ miles per gal. in the ordinary pick-up and delivery work that the trucks are required to do. Our firm is in the structural steel business and occasionally the loads on the trucks are very excessive. We have been

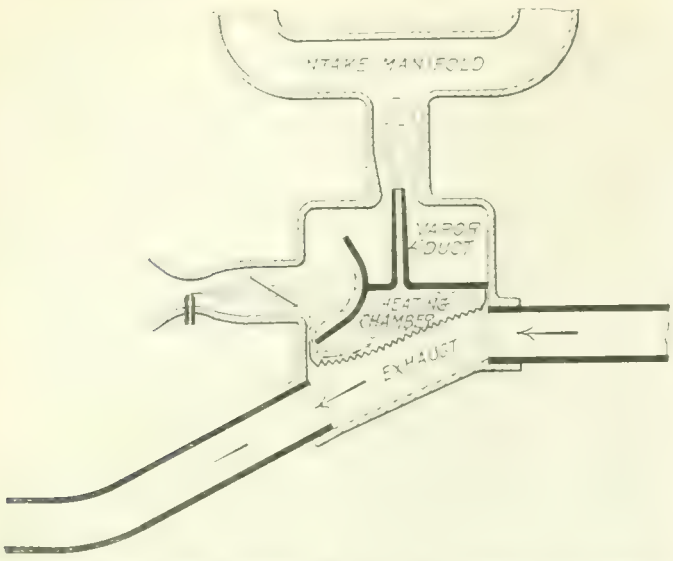


FIG. 6—A FUEL FEED SCHEME IN WHICH A SEPARATOR LOCATED JUST BEYOND THE CARBURETER IS UTILIZED TO SEPARATE THE LIQUID UNVAPORIZED GASOLINE AND PASS IT TO A HEATING CHAMBER FOR VAPORIZATION

keeping weekly records of the performance of the trucks running on kerosene. Recently one averaged 7.1 miles per gal. and the other 6.8 miles.

This same manifold equipment is used on our tractor engines for alcohol burning. We change the compression-pressure raising it to 110 lb. per sq. in. I was pleased at the confirming remarks[4] of both Mr. Midgley and Dr. Dickinson regarding the use of alcohol as fuel. We have to use alcohol as fuel on tractors in certain localities and have been forced to work out a vaporizing system which will handle it properly; this arrangement does so, although we have to apply a considerable amount of heat to the intake air. I sometimes think our minds are running in a groove. Some of us are hypnotized, I believe, by the word "petroleum." If we would remember that there are other things than petroleum that might be used as fuel and devise means to make them at a reasonable price, it would not cost nearly as much to learn how to get another fuel as it did to learn how to get the gasoline of today. If we should do that, we would solve the fuel-supply problem in part at least.

F. C. MOCK:—An additional reason for attacking the fuel problem in this way is, I think, that when successful we shall be through with the problem of distribution. I believe that within a few years we shall have reached a point where we shall have no distribution trouble, and we shall consider the practice of leading liquid fuel into the intake-pipe and from the intake-pipe to the valves as engineering barbarism.

Fig. 6 illustrates what I have in mind. The principle of having a separator just beyond the carbureter, separating out the liquid unvaporized gasoline, passing it to a heating chamber and allowing it, when vaporized, to rejoin the airstream is utilized. This was proposed a long time ago, and no originality is claimed for the idea. The difficulty lies in getting satisfactory separation, for this is really very difficult if there is any great quantity of liquid fuel to handle, but if one can accomplish such a separation, there is no difficulty in getting enough heat from the exhaust for fuels much inferior to kerosene. The limitation of temperature lies purely in how much the vapor will raise the total mixture temperature when it condenses again as it rejoins the airstream; and one can keep the temperature down by feeding cold air from outside the hood to the carbureter. If we can develop this principle of separation, and I am sure that it can, and will, be developed within a few years, it will open up a considerable extension of internal-combustion engine design, as there will be no limitations of manifold shape, or air velocity, because the manifold will be handling a fog. In an engine design where it is desired to have the intake-valve ports on the opposite side of the engine from the exhaust, this heating chamber and the carbureter can be put on the exhaust side of the engine and a connection made to the intake across or through the engine.

By the development of this idea, and the work which Mr. Midgley and his associates are doing in developing an anti-knock element, I think we shall have the automotive fuel problem pretty well solved within a few years.

MR. HORNING:—I wish to support Mr. Dorris, Mr. Mock and the others in what they have said and to emphasize fundamental facts. One of the great losses in power in an engine today is due to the fact that we are dealing with fuel as a liquid. A fundamental in chemistry and physics is that one cannot burn a liquid. Combustion is a phenomenon of combinations of substances at a rapid rate, and they cannot combine rapidly enough to generate heat unless they are in the form of gases. We are putting into engine cylinders liquid that cannot enter into the combustion and cannot contribute toward power, and one of the great sources of power loss is that we are not getting out of the fuel an amount of energy that is in it. This is the carburetion efficiency that I have mentioned before and becomes a large factor in badly distributing systems.

Recently, we investigated so-called hot-spots. We used a manifold equipped with various devices and arranged to supply 1 lb. of fuel to the carbureter, taking off all the heavy fuel that was deposited on the wall of the manifold. We collected the unvaporized fuel in the manifold, just before it entered the cylinder. At 400 r.p.m., running idle, we took out 50 per cent of the fuel and the engine did not show it; the engine ran just as well. This 50 per cent was in the form of a liquid that had a specific gravity of from 48 to 51 deg. Baumé. The original fuel had a gravity of 58 deg. Baumé. We should be able to transform the 50 per cent loss into a gas that we can burn.

The difference in temperature is not an inherent characteristic of the manifold; it is a physical characteristic of the fuel. The heat of vaporization controls it. One can change an engine from gasoline to kerosene and see the temperature rise automatically. The first time I did that I thought I had designed a wonderful automatic manifold. However, the fuel was entirely responsible. It takes less heat to vaporize kerosene than it does to vaporize gasoline. It requires 140 B. t. u. to vaporize 1 lb. of gasoline and 105 B. t. u. to vaporize 1 lb. of kerosene. It requires a higher temperature to vaporize kerosene, however, and we ought to consider that when designing manifolds.

MR. BREWER:—When I began experimenting with the lighter fuels, in connection with my original designs of manifold, a satisfactory attempt was made to drain the fuel off in a similar way to that used by Mr. Dorris but, instead of using external pipes, grooves were embodied in the design of the manifold so that if any precipitation occurred, which was actually the case only at night after the engine had cooled and there was a certain condensation in the manifold, the precipitate would run back into

[4] See pp. 260 and 271 of this issue.

the intake-pipe. So far as I could see, these manifolds were always designed with the location of the heated area where it should be. In many designs of manifold one finds that the designer has failed entirely to realize where the precipitation would occur and locates the heating surface in the wrong place. Small modifications in a manifold make all the difference, but that is not often realized.

Another point not generally appreciated is that in the natural condition of an automobile everything is cold; a manifold that will operate perfectly well when it is hot does not operate satisfactorily when cold, and it is extremely difficult to get cold distribution. In designing a manifold I always try to run the whole gamut, just as the user would do, from a cold engine and cold distribution, working onward and eliminating the defects in the hot distribution afterward. Mr. Mock pointed out that separation of the liquid from the airstream in the initial stages is of very great importance. But I think the separation of the liquid in various parts of the manifold in the Dorris design will affect the mixture strength reaching the different cylinders. Separation should occur from the main stream; so, the portion that passes the separator should be homogeneous and remain in that condition under all conditions of absolute pressure.

Much can be done in manifold design by varying the temperature with the absolute pressure; that is not often borne in mind, but it is an interesting point in design. One can heat the vapor to a temperature and a condition where it remains fixed and, after it becomes thoroughly fixed in that condition, one can lower the temperature without getting precipitation.

CHAIRMAN O. C. BERRY:—I wish to add emphasis to Mr. Brewer's point that the place to separate the liquid fuel is at the main stream in the intake manifold, before it has been divided into the different portions going to the various cylinders. This is the only way in which vaporizing the fuel can aid distribution. An over-rich or over-lean gaseous mixture at any cylinder is just as much to be deplored as a poorly distributed wet mixture.

As one makes the mixture lean in striving for greater economy, there are certain bad effects to watch for. The car may run along very well at constant speed, but when one suddenly opens the throttle for acceleration, the engine dies. The reason is that when the throttle is opened suddenly, the air gets ahead of the gasoline and the mixture that reaches the cylinder is temporarily lean. In designing manifolds for heating the liquid portions and vaporizing them, I think we must bear in mind that one of the essential points is to delay this liquid as little as possible. The greater the delay is, the greater the task the carbureter has in overcoming manifold difficulties. We must get the gasoline vaporized as quickly as possible and make the delay as short as possible.

ELEMENTS OF AUTOMOBILE FUEL ECONOMY

BY W. S. JAMES

THE paper analyzes and states the factors affecting the power requirements of cars as rubber-tired vehicles of transportation over roads and the factors affecting the amount of power supplied the car as fuel to produce at the road the power required for transportation. Quantitative values are given wherever possible to indicate the present knowledge of the relation between the factors involved, and the text is interspersed with numerous references, tables, charts and diagrams.

Among other important factors specifically discussed are mixing and vaporization, charge quantity control, the heat of combustion, gas-pressure, transformation loss and power transmission efficiency.

Six appendices contributed by other associates of the Bureau of Standards are included. These are illustrated and treat in detail the subjects of the influence of air and fuel proportions upon engine efficiency and power, the metering characteristics of six stock carbureters, the mechanical efficiency of engines with particular reference to part-load conditions, ignition timing, fuel knock and the relative merits of large slow-speed and small high-speed engines. [Printed in the June, 1921, issue of THE JOURNAL]

THE DISCUSSION

MR. JAMES:—This paper is of an outline character. It is a compilation or analysis of the factors that are involved in automobile fuel economy, arranged somewhat like a filing system. We have attempted to put behind each index card what information we could find, and to state the fact when no information was available.

The process involved in the production of power at the rear-wheel rims from fuel supplied to the engine can be divided into the four main groups of (*a*) the preparation of an explosive mixture of fuel and air, (*b*) the transformation of the chemical energy latent in the explosive mixture into gas pressure, (*c*) the transformation of the gas pressure produced into crankshaft torque and (*d*) the transformation of crankshaft torque to thrust at the road surface. The division lines between the first three items are not definite and can be drawn in several ways.

In commenting upon the portion of the paper dealing with the power requirements of cars, it should be noted that our knowledge of wind-resistance constants is meager, that the rolling resistance of a given car is practically independent of the speed, that the rolling-resistances of various road surfaces are extraordinarily variable and uncertain and that the major portion of the power required on the level when driving at low speed is necessary to overcome rolling resistance and at high speed to overcome wind resistance.

Temperature has been found to have far more effect than pressure on the lean limit of inflammability, which is the one that is of interest when considering fuel economy. When we have learned which mixture will explode, then the fuel and air can be proportioned to give either maximum economy or maximum power, as we desire. In Appendix 1 Mr. Sparrow points out a fact that should be borne in mind by those who conduct dynamometer fuel-economy tests of engines. Very careful work has been done in measuring the power output and the fuel consumption of engines under constant throttle-positions, or else constant manifold-depressions at constant speeds with varying fuel-air ratios. When the brake thermal efficiencies are obtained from this work, the results have been applicable to either conditions of constant manifold-depression or throttle-position. Neither of these conditions is encountered in a car on the road. When driving at say 25 m.p.h. a definite amount of power is required;

if the fuel-air ratio is changed and the car is still driven at 25 m.p.h., the same amount of power will be required. The manifold depression has changed as the mixture has been made leaner, for example, and the power decreases although the manifold depression is the same. To maintain a car speed of 25 m.p.h. the throttle must be opened. Mr. Sparrow has recomputed some of these data to show the ratios of air to fuel that will give maximum economy when delivering constant power at constant speed. The lower curves in Fig. 7 of my paper show that absolute manifold pressure has no effect whatever on the indicated thermal efficiency except at low throttles. The curve for a manifold pressure of 30 cm. (11.81 in.) shows that the engine cannot run on a mixture leaner than about a 13½ to 1 ratio; therefore, it becomes evident that, in general, the mixture ratio for maximum economy is the leanest mixture on which an engine will run regularly.

Fig. 1 of my paper shows the effect of the pressure of exhaust gas on the maximum mixture-ratio that can be used in an engine. The data for the case of the valve-in-head engine were taken from published data on the maximum air-fuel ratio at which the engine would run at various manifold depressions, from 300 to 650 mm. (11.81 to 25.59 in.), and plotted against the percentage of the weight of inert gases of the total weight of the cylinder contents. The general indication of the curve is that as the weight of inert gases increases the mixture ratio at which the engine will run becomes smaller and smaller. This is one of the limitations of a throttling method of charge control.

Figs. 2 and 3 of my paper indicate the difficulty of the problem of mixing the fuel and the air. If the cube representing the liquid has a unit volume, the fuel in the vapor state has a volume of about 200 and the air a volume of about 8000. Of this air only about 25 per cent is oxygen. The residual products of combustion also are added to the air. Fig. 2 represents conditions at full-load and Fig. 3 the conditions at about 20-per cent load. All this mixing must take place in a very short length of time. The problem of fuel and air mixing probably is the most important one upon which work could be done to increase the fuel economy of Otto-cycle engines.

Of the two possible methods of accomplishing mixing, vaporization and atomization, the major emphasis has been placed on vaporization, but there are great possibilities in atomization. Mr. Horning has stated that when liquid fuel is admitted to the cylinder, it never burns. I believe that is not true, because there is a large amount of heat available within the cylinder itself for vaporization. First, there is enough heat generated in compressing the charge to vaporize practically all of the fuel; second, from full-load to part-load and over the entire range of speeds covered, it will be found that there is from an equal amount to 100 per cent more heat available in residual exhaust gas to vaporize the entire weight of fuel entering. These facts were indicated last year in a paper we presented on hot-spots[5] showing that, at constant speed and load, it made no difference in fuel economy how much or how little the intake air or the manifold was heated. These results can point only to the fact that the fuel was vaporized somewhere between the time it entered the intake port and the time it was fired. We knew at that time that liquid gasoline was entering the cylinders when the air and the manifold were unheated.

Regarding charge quantity control, I wish to say emphatically that the pumping losses in the Otto-cycle engine are not as great as they have often been stated to be. The decrease in economy is about 20 per cent at 20-per cent load.

In the transformation of the chemical energy of the fuel, which we will assume to be in the cylinders and thoroughly mixed, into gas pressure in an engine cylinder, the two factors involved are the increase of pressure due to an increase of temperature and an increase of pressure due to an increase in specific volume.

It has been shown definitely that the ignition of a charge is unaffected by the kind of spark used, as long as there is a proper mixture. It has not been shown, however, that the character of the spark has no effect if there is not a proper mixture. We have been able to show very recently that the characteristic of a spark, when the conditions of firing are poor, has a very marked effect. From what Mr. Sparrow has written in Appendix 4 it is clear from Fig. 17 of my paper that the change in spark-advance necessary for change in load is of much more importance than the change in spark-advance necessary for a change in speed. The increase in spark-advance necessary with reduced load is possibly due to the presence of a greater percentage of inert gases.

We know practically nothing about the rate of heat loss from the gases during combustion, and there is very little reliable information on the rate at which energy is liberated, although in all probability that is one of the most important outstanding problems today, because detonation is involved in it. Fig. 4 of my paper gives two curves, computed from indicator cards, showing the rate at which energy is evolved in a cylinder. The one on the left is for commercial fuel, and the other for aviation fuel. All I can say about these is that they are different; we do not know why.

Appendix 5, by Dr. Dickinson, is an excellent summary of what we do and do not know about detonation. He lists the things that we think affect it, and states three theories as to why it happens. Regarding the three theories, Dr. Dickinson has summarized the situation very well in the last paragraph of Appendix 5.

With regard to the transformation of gas pressures into crankshaft torque, there are four sources of loss in a gas-pressure crankshaft-torque transformation-mechanism that refer directly to the mechanism itself. The air-cycle efficiency as commonly used gives the value for loss from incomplete expansion very correctly, but nothing more.

The next most important losses are those due to charging the cylinder and to mechanical friction. The top curve in Fig. 16, in Appendix 3, shows the percentage of loss due to pumping; it is about 20 per cent at about 20 per cent of full load. When this work was being done we had an idea that we could eliminate all pumping losses by putting in exhaust gas; but we found that the pumping loss decreased slightly as soon as we added exhaust gas, and that the air-fuel ratio at which the engine would run was decreased at the same time. The decrease in economy due to the necessity of running with a richer mixture was four or five times the gain from the decreased pumping-loss.

The importance of jacket-water temperature on friction losses is indicated in Fig. 15 of my paper. It is often thought that if the cylinder-heads are removed and the friction horsepower measured, and the cylinder-heads are replaced and the friction horsepower measured again, the difference between the two is the pumping loss. Unfortunately, this is not true. The error is probably due to a difference in mechanical friction under load. That is disheartening, because it is convenient to add the brake

[5] See THE JOURNAL, August, 1920, p. 131

horsepower to the friction horsepower and get indicated horsepower. The values obtained by this method are near the correct values and are probably all right for general purposes, but it has never been proved absolutely that the sum of the brake and friction powers gives the indicated power. However, what I have mentioned is the only evidence we have ever seen that this is not true.

In Appendix 6, on the relative merits of large slow-speed and small high-speed engines, Mr. Sparrow has taken the power required to drive a car on a level road as given in A. L. Nelson's paper on the Fuel Problem in Relation to Engineering Viewpoint,[6] and the brake horsepower developed for an engine that we have at the Bureau of Standards. The brake-horsepower curve is given in the second curve, marked *X*, in Fig. 19 of my paper, and it has been assumed that the brake horsepower of the engine has been increased 50 per cent by the addition of two cylinders; in other words, comparing four and six-cylinder engines of the same bore and stroke. It has been assumed also, as shown in the two lower curves, that the friction power of the larger engine is 1½ times that of the smaller engine.

In Fig. 20 of my paper the power curves given in Fig. 19 have been put on the basis of miles per hour. Rear-axle ratios of 3 to 1 and 4½ to 1 have been assumed for the larger and the smaller engines respectively. The power curves show practically no difference in performance.

In Fig. 21 of my paper Mr. Sparrow has computed the fuel consumption in pounds per brake horsepower-hour for the two engines and also the miles per gallon. In computing the brake horsepower for the larger engine he has made the assumption that the friction power changes with the throttle position, in accordance with the lower curve in Fig. 21. When the results of these computations are put on the basis of miles per gallon, there is about a 7½-per cent difference in favor of the larger slower-speed engine. But of course the weight will be increased when a larger engine is used, and it has been assumed that the engine weight must be increased 50 per cent. This results in an increase of the total car weight of about 7½ cent and we get practically equal performance in the two cases if everything is done to favor the small high-speed engine. As Mr. Sparrow states, this analysis does not prove the superiority of either type of engine for every case, but it raises a point which every builder of small high-speed engines would do well to investigate.

There remain only the losses through the drive system. The universal-joint efficiencies are very high, particularly at medium powers. The gearbox efficiencies vary from 70 to 90, and the rear-axle efficiencies from 70 to 98 per cent. Improvements in all those possibly can be made, but they are affected so much by the type of lubrication that it is very difficult to draw any definite conclusions.

One point that I would like to make is that I believe the automotive industry has neglected the accessory manufacturer. We have 10,000,000 or more cars on the road today, and the car builder seems to lose all interest in his product after it is out of the factory, particularly when it is two years old. But these are the cars that are using up the fuel. It probably is possible to increase fuel economy very markedly by changing the intake system. There are many devices on the market for doing this; some of them are good, and others are bad. Why do not the car builders go over the list of devices that are available? They know what their cars can do, and they can recommend devices that will give car users increased service.

THOMAS MIDGLEY, JR.:—I consider Appendix 5, by Dr. Dickinson, as a truly remarkable summation of the physical characteristics affecting detonation and by far the most thorough presentation of facts upon this subject that has been presented. Whereas Dr. Dickinson has proved unquestionably the existence of the wave-front by an excellent mathematical treatise on the subject, I simply wish to call attention to a visualization that is possible on this point. In the several indicator-cards which we have presented to the Society a very definite rapid rise of pressure and a corresponding quick decrease evidenced the knock. The excellent work of the Bureau of Standards has confirmed this rapid rise and drop. Dr. Dickinson has proved beyond question that the rapid rise is of such a mathematical value that it could not be caused by a uniform pressure of such a value throughout the combustion-chamber. I wish to point out that, were this pressure rise caused by a uniform pressure in the combustion-space, we would then have the expansion-line starting from the peak of this curve and not have a rapid drop in pressure. In other words, while the rapid rise in pressure might be explained by a uniform pressure throughout the combustion-chamber in theory, I defy the adherents of such a theory to explain how this pressure falls so rapidly.

In reply to Dr. Dickinson's remarks concerning the uniformity of distribution of this detonation wave, giving no localized effect, I refer to the paper on the Nature of Flame Movement in a Closed Cylinder, by C. A. Woodbury, H. A. Lewis and A. T. Canby.[7] I believe that the proper interpretation of their sulphuric-ether photographs was not made. The photograph of the wave front passing down a bomb was made on sulphuric ether, which is one of the violent knocking fuels. It was started with a spark-plug at one end and proceeded throughout the bomb to a uniform bright flash. It is this bright flash that we believe contains the wave-front traveling at a high rate of speed, the striking of which causes the sound and the chemistry of which we believe to be the preferential burning of hydrogen. We think this is the greatest limiting factor of thermal efficiency. It is evident that this bright flash passed back fully as rapidly through the burned mixture as it did through the unburned or partially burned mixture, and I feel fairly certain that this explains what Dr. Dickinson has observed as the uniformity of temperature rises and pressure effects.

DETERMINING DEW-POINT OF GASOLINE

PROFESSOR WILSON:—I will sketch briefly some of the work that we have been doing at the Massachusetts Institute of Technology to determine definitely the dew-point of gasoline and kerosene when mixed with air in various proportions.[8] In developing a carbureter or manifold with special arrangements for heating the mixture to secure complete vaporization, it is especially desirable to know the minimium temperature to which the mixture would theoretically need to be heated. If I should say that 100 deg. fahr. would be proper if one had a perfect manifold, then everyone would realize that volumetric efficiency is lost by heating the mixture to 175 deg. cent. (347 deg. fahr.), which may seem necessary to get complete vaporization in a given manifold. That is exactly the case for present-day gasoline. It is rather

[6] See THE JOURNAL, February, 1921, p. 101.

[7] See THE JOURNAL, March, 1921, p. 209.

[8] This subject has since been discussed in more detail in an article entitled Condensation Temperatures of Gasoline-Air and Kerosene-Air Mixtures, by Robert E. Wilson and Daniel P. Barnard, IV, which will be published in an early issue of THE JOURNAL.

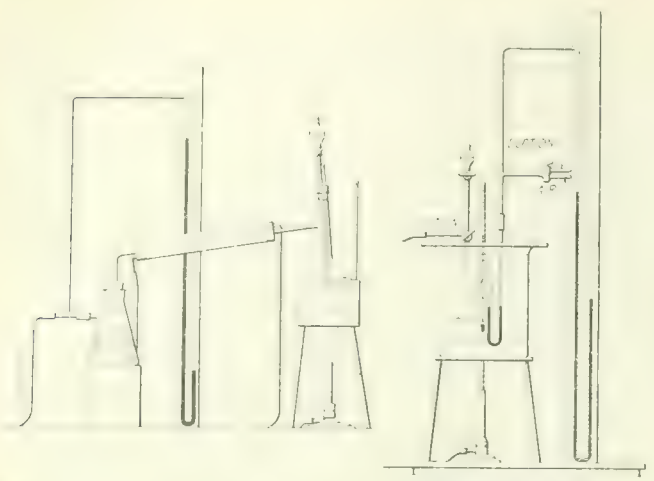


FIG. 7—APPARATUS AT THE LEFT FOR THE PREPARATION OF EQUILIBRIUM SOLUTIONS USED IN DEW-POINT CALCULATIONS AND AT THE RIGHT THAT EMPLOYED FOR DETERMINING THE VAPOR PRESSURE

surprising that these facts have not been brought to the attention of automotive engineers.

In developing distribution systems we are limited partly by the carrying-capacity of the air, which is surprisingly high, and partly by too slow a rate of vaporzation. If we can separate these two factors into their component parts and determine what part of the difficulty is due to the inherent limitations of the fuel and the carrying-capacity of the air, and what is due merely to the mechanical difficulty of getting the heat of vaporization into the unvaporized drops with sufficient rapidity, we will be able to focus our attention on the right method of progress. This will also give us a definite method of determining the efficiency of a given hot-spot manifold, simply by determining the carrying-capacity of the air for the particular fuel on which the experiments were made, and finding what temperature actually must be reached in a given manifold to obtain complete vaporization.

Unfortunately, however, there has been no satisfactory method of measuring the dew-point of a mixture of gasoline and air. The simple methods which are used for pure compounds are not at all applicable in this case, because gasoline is a mixture of compounds of widely different volatility. One might ask why we do not measure the vapor pressure of gasoline, since that is the method of determining the dew-point of a pure compound. The trouble is that the liquid which first separates out from a completely vaporized mixture does not have the same composition as the gasoline as a whole, nor does it have the same composition as the last 10 per cent which distills over, as was tentatively assumed by Frank A. Howard in the paper that he presented at the 1921 Annual Meeting.[9]

If, however, we could get some of the mixture that first separates out of the airstream on cooling, and measure its vapor pressure, it would be a comparatively simple matter to calculate the dew-points. It is difficult to get enough of that which first separates out and be sure it represents the equilibrium between the vapor and the first drop of liquid that comes out. The method which we have developed for accomplishing this involves the use of a distillaton flask, such as is shown at the left of Fig. 7. This is filled to a certain level with the fuel in question and that level is maintained accurately by observing a hook-gage that just comes to the surface. The flask is put into an oil-bath, the fuel in question is poured into the flask through the upper reservoir and distillation is begun. A thermometer records the temperature of the liquid boiling in the flask.

If a given sample of gasoline is used, it will start boiling at the initial boiling-point of that sample, but we know that the vapor that distills off first is more volatile than the original substance and, therefore, the liquid that stays behind is less volatile. We continue to add fresh fuel to keep the level constant, and the vapor passing out is still richer in the lighter ends; so, we concentrate the less volatile portion in the flask. While we are doing that the boiling-point continually rises, as shown by the thermometer in the flask. Eventually, however, we reach a point where the temperature remains absolutly stationary. We continue the process for 30 min. more to be certain that we have a condition of equilibrium. At that time the composition of the vapor that leaves the flask must be exactly the same as the composition of the liquid that comes in, because input must equal output when steady conditions have been established. Therefore, the liquid in the flask accurately represents the liquid that is in equilibrium with the completely vaporized fuel, or that which would be condensed out first on cooling the air mixture, and that is exactly what we want. Then we remove that from the flask and measure its vapor pressure.

Figs. 8 and 9 show different forms of the distillation curves of the three fuels used; Socony gasoline, Socony kerosene and an artificial high-end-point gasoline which we made by mixing 100 parts of gasoline with 25 parts of the first half of the kerosene fraction. Fig. 7 shows most clearly the comparison of the composition of the original fuel and of the equilibrium solution obtained by the method that I have described. It will be noted that the equilibrium solution contains not only some of the high ends, but some of the lower ends. As a matter of fact, the average boiling-point of all of the equilibrium solutions comes at about the 85 per cent point in the distillation of the original fuel.

I will not describe the method that we used to measure the vapor pressure of the equilibrium solutions, but we obtained very accurate data on all three fuels, using the apparatus shown at the right of Fig. 7, from which we are able to calculate the temperature of initial condensation as a function of the richness of mixture and of the total pressure. Of course, when we are working in vacuum or under compression in the cylinder, we have other than a pressure of 1 atmosphere.

FIG. 8—DISTILLATION CURVES FOR FUELS AND THEIR EQUILIBRIUM SOLUTIONS

[9] See THE JOURNAL, February, 1921, p. 145.

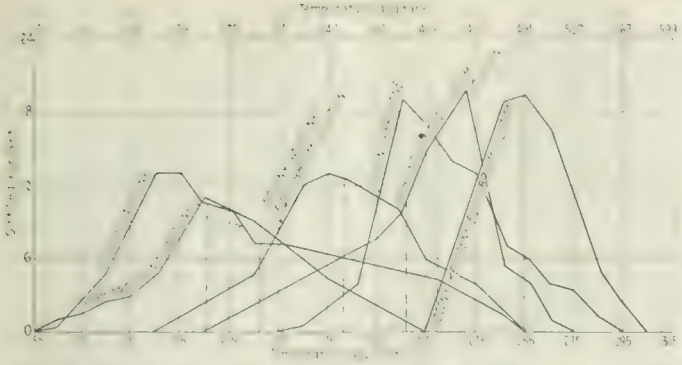


FIG. 9—DIFFERENTIAL DISTILLATION CURVES FOR THE FUELS SHOWN IN FIG. 8 AND THEIR EQUILIBRIUM SOLUTIONS

Fig. 10 shows the complete results on Socony kerosene. It will be noted that for a 15 to 1 mixture at a pressure of 1 atmosphere, 104 deg. cent. (219 deg. fahr.) is the point at which condensation begins. Fig. 11 shows the results for all three fuels, and not only the temperatures at which condensation begins, which values we have determined accurately, but also approximate values for partial-condensation temperature. It should be remembered that these results are strictly true only in case a condition of equilibrium is attained. It shows what can be done if our mechanical contrivances are perfect. Fig. 11 shows that, under the specified condition, the Socony kerosene has a dew-point of 104 deg. cent. (219 deg. fahr.), the artificial high-end-point gasoline a dew-point of 57 deg. cent. (135 deg. fahr.) and the ordinary gasoline a dew-point of 35 deg. cent. (95 deg. fahr.). In other words, in the case of that particular gasoline, which may be somewhat better than the ordinary, every degree we have to heat our mixture above 95 deg. fahr. is because our mechanical contrivances are not sufficiently good. It shows the great importance of developing even further the hot-spot manifold proposition, and that the fuel itself has no inherent limitations to make it particularly difficult to obtain complete vaporization.

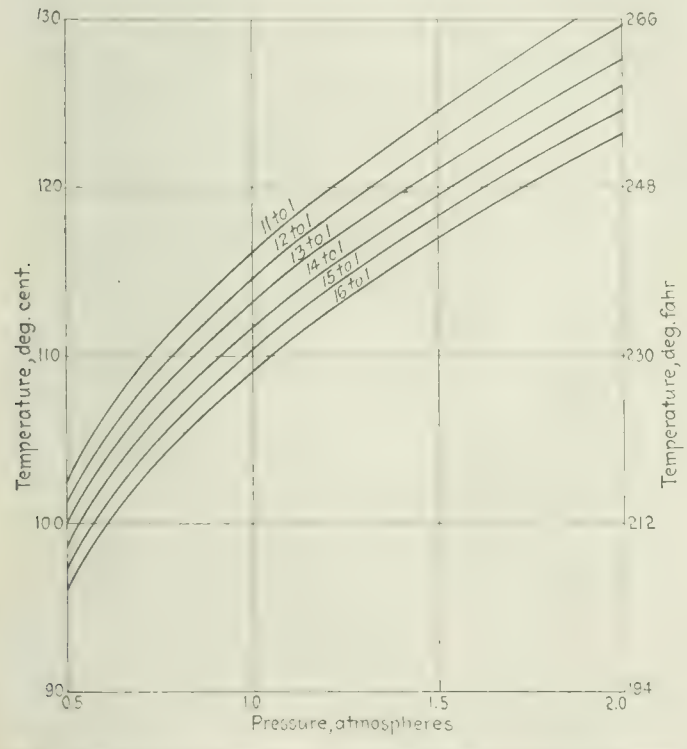


FIG. 10—INITIAL CONDENSATION TEMPERATURES OF THE KEROSENE-AIR MIXTURE

I will show also the essential results which we have obtained as to the amount of heat required to vaporize the fuels. Fig. 12 shows a total heat curve for liquid kerosene. With regard to what Mr. Horning has said, I wish to point out that while the heat of vaporization of kerosene is less, that is only a small part of the heat that we must put into the kerosene to get it into the air-stream, because we must put specific heat in even though we have liquid kerosene. The heat of vaporization of kerosene is very low, so that the specific heat becomes an important factor. This comes in through heating up a liquid without getting vaporization. In a pure compound the curve rises sharply because it all boils at the same temperature; but kerosene only boils off gradually, so the curve rises gradually. The differences between the extension of the lower line and the two higher ones repre-

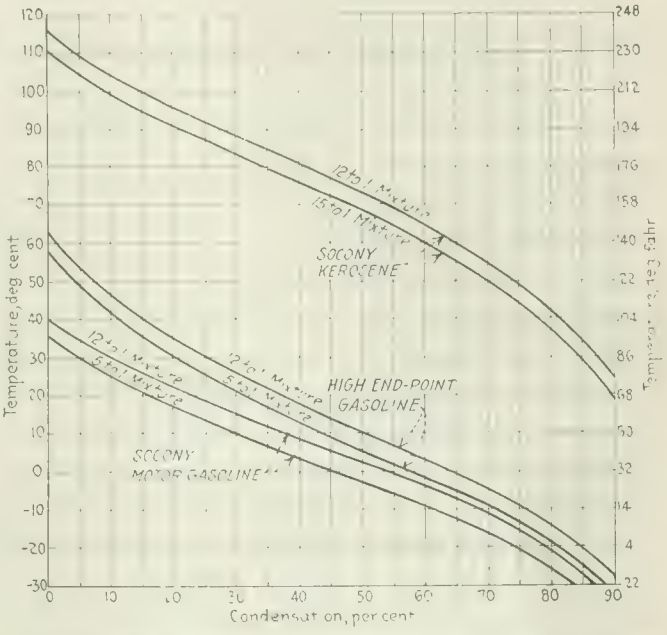


FIG. 11—TEMPERATURES OF PARTIAL CONDENSATION OF AIR-FUEL MIXTURES AT A PRESSURE OF 1 ATMOSPHERE

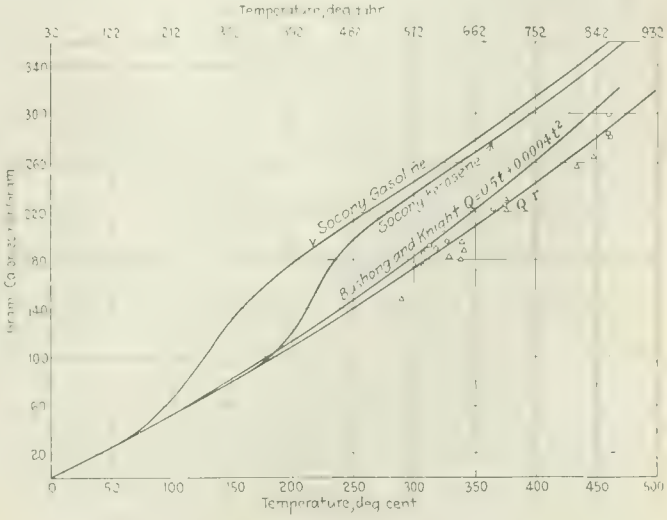


FIG. 12—TOTAL SENSIBLE HEATS OF KEROSENE AND GASOLINE

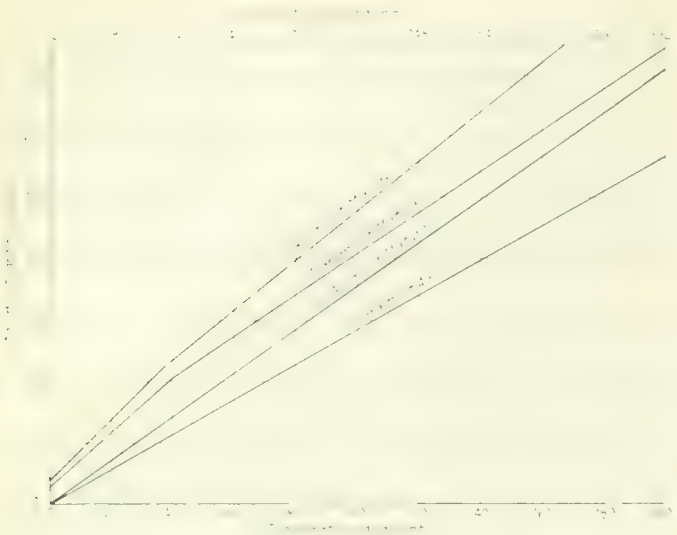


FIG. 12—TOTAL SENSIBLE HEATS OF A KEROSENE-AIR MIXTURE

sent the heats of vaporization. That is slightly less than one-half of the total heat at the boiling-point. As a matter of fact, it does take more heat to get kerosene into an airstream than is required for gasoline, because of the higher temperature to which it must be heated.

Fig. 13 shows the total heat of air and of mixtures of air with kerosene. From this we can calculate how high a temperature is needed to heat the gasoline so that it can be mixed with cold air and completely vaporized.

MR. GERNANDT:—We advocates of the high-compression engine appreciate what is being done on manifold construction, but we ask why an engine should be complicated with a miniature distillery when the fuel can be burned without distilling it, just as it is pumped out of the ground. The complication is very slight in developing an engine to burn the heavier fuels without distilling them.

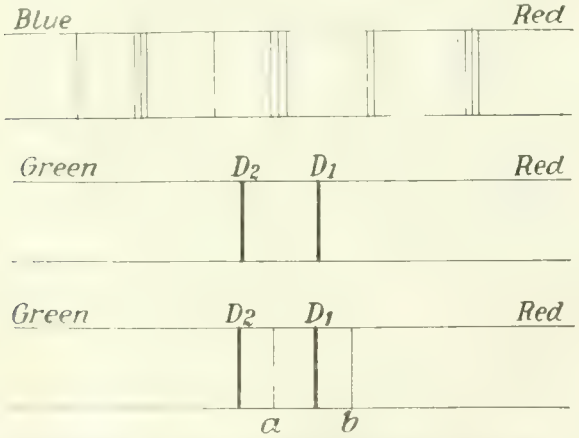


FIG. 14—DIAGRAM SHOWING HOW THE SPECTROSCOPE CAN BE USED AS AN INDICATOR OF CONDITIONS IN AN INTERNAL-COMBUSTION ENGINE CYLINDER

MR. BREWER:—We have given much attention to the fine details of fuel combustion but, in general, I think we have rather lost sight of the losses in the automobile itself. I wish to call attention to the enormous amount of power that is dissipated in accelerating the mass of an automobile including its unsprung weight as it passes on the road. Mr. James referred to this briefly. I made many experiments some years ago on power loss. On one racetrack I found that the power loss even on one circuit of the track varied enormously, and that from day to day one never could get two readings that were alike. In Mr. James' paper are given some figures for the rolling resistance of cars, among them a Benz. Some of this is referred to in Wimperis' paper and, as a matter of fact, I made the experiments on the Benz, and they are the highest recorded speeds with the Wimperis accelerometer that have ever been made. I made observations at a car-speed of 120 m.p.h.

SPECTROSCOPIC POSSIBILITIES

MR. MIDGLEY:—Because of a statement I made at the 1921 Annual Meeting with regard to the spectroscope, I wish to say that we have continued that work, and that we cannot get a trace of the green band in the spectrum. Some interesting spectroscopic possibilities have developed in the recent work. In Appendix 5 to Mr. James' paper the statement is made that the pressures in the wave-front reach a limit between 5000 and 7000 lb. per sq. in. and that it is very doubtful if any indicator in use is capable of responding to such instantaneous pressure, other than to register a kick, so to speak. We have in the spectroscope an indicator that has been able to indicate the position of the atoms in a molecule, the size of the positive nucleus at the center of a molecule and the speed at which heavenly bodies approach us. These are speeds that we could not measure with any speedometer. If the light coming out of a cylinder passes through a spectroscope, the spectroscope divides that light into band-like colors as indicated in the upper portion of Fig. 14. Different elements give definite, positive lines. The middle drawing of Fig. 14 shows the yellow lines of sodium, called the *D* lines, magnified. The position of these lines is affected by pressure, although it requires a great pressure to move them very far. The lines at *a* and *b* in the diagram at the bottom of Fig. 14 show how these lines would vary from the originals under a pressure of 4500 lb. per sq. in. So, in this device we have an indicator of extremely small inertia that we are trying now to make use of to measure this pressure in the wave-front exactly.

DEVELOPING A HIGH-COMPRESSION AUTOMOTIVE ENGINE

BY FRED C. ZIESENHEIM

THE paper is divided into three parts; the fuel problem, the selection of the most economical internal-combustion engine for adaptation to automotive purposes and the details of the development work undertaken.

After stating the fuel problem, inclusive of production, volatility and price charts, the methods of increasing the engine-fuel supply, the characteristics of present engine fuels and general considerations regarding the selection and adaptation of the most economical engine are discussed. Classifying internal-combustion engines as being of low, medium or high compression, the essen-

tial factors, advantages and disadvantages of each class are commented upon in detail.

High-compression engines are classified, as to their method of injecting the fuel into the combustion-chamber, into the three general classes of air, gas-pressure and mechanical injection. These are described and analyzed at length, numerous charts and diagrams being included, and a lengthy summary of all the essential factors thus far considered follows.

The development work on mechanical injection that was done in the laboratory of the Carnegie Institute of Technology, Pittsburgh, is illustrated and described in detail. The two methods, variable-pressure and constant-pressure, are discussed separately at length. [Printed in the July, 1921, issue of THE JOURNAL]

THE DISCUSSION

F. C. ZIESENHEIM:—Supplementing my paper, the principal disadvantage of the Diesel engine for development in small units is the air-compressor. The air for injection is at a pressure of from 200 to 600 lb. per sq. in. higher than the compression pressure, which is about 500 lb. per sq. in. and is sufficient to cause autoignition of the injected fuel. To pump up a small quantity of air to a pressure of 800 to 1200 lb. per sq. in. requires an air-compressor of considerable size and an air-compressor is a mean piece of apparatus at best; most of the trouble that is encountered in the operation of Diesel engines can be attributed to it. Consistent progress is being made in eliminating the troubles, but many of the conditions for trouble still exist; for instance, in the lubrication of the Diesel-engine air-compressor, if too much oil is used, the air receivers will be charged with an oil vapor that is explosive and often causes considerable damage.

The statements in my paper in regard to the Pittsburgh Filter & Engineering Co.'s Brons-Hvid engine were based on information obtained during the period of development. This company has since informed me that the troubles mentioned do not exist in the present engine.

The Steinbecker engine is a German gas-pressure-injection engine. It is rather odd, in that connection, that the Germans stated emphatically that the Diesel engine was absolutely the only form of high-compression engine that was possible; but, as soon as Steinbecker announced his engine, they immediately agreed that other types could be built and said that they had constructed one.

Another point in regard to the Diesel engine is that the expansion of the injection air causes a refrigeration effect. This requires carrying the compression to a higher pressure than is necessary in a mechanical-injection engine. Referring to Fig. 4 of my paper, which gives the air temperatures for different final compression-pressures, for 350 lb. per sq. in. compression we get about as low a temperature for ignition as is permissible for starting. Of course, after the engine has warmed up and is operating, we can use a lower compression-pressure. Some engines use other means of securing heat when starting; the engine then runs on autoignition.

There are two types of mechanical-injection engines. One uses the variable-pressure method, in which the pump pressure opens the valve; in the other, the fuel is maintained at a constant pressure and the injection valve is lifted mechanically by a cam.

My reason for selecting the constant-pressure method of fuel injection in preference to the variable-pressure method, strictly for small units, is that with the latter the injection of a very small quantity of fuel is rather difficult. We may be able to measure the fuel definitely at the pump, but to inject that particular quantity into the combustion-chamber is another matter. A very small leakage from the fuel system will amount to more than the quantity of fuel one is trying to inject, even on full load.

A constant-pressure fuel-valve is shown at the center in Fig. 11 of my paper. The fuel builds up under the differential plunger, but the lift spring shown at the top is sufficient to keep the valve closed until the cam lever lifts the valve spindle and permits injection of the fuel.

ALCOHOL AND SHALE OIL

MR. MIDGLEY:—I agree with Mr. Ziesenheim thoroughly that we cannot hope for coal products that will exceed approximately 20 per cent of our fuel requirements in light oils, benzol and the like but, in regard to his analysis of the fuel situation of the future, it is rather a new thought to me that to produce alcohol the use of as much heat as we can get from the alcohol is required. I have made some alcohol without using very much heat. The alcohol situation and its relation to the fuel of the future can be described by saying that from our cellulose waste products on the farm such as straw, corn-stalks, corn-cobs and all similar sorts of material that are virtually thrown away at present, we can get, by present known methods, enough alcohol to run our automotive equipment in the United States. The process is a process of hydrolysis, fermentation and distillation. However, the yield is only about 10 per cent and the alcohol would cost us about $2 per gal. I think that it is the cost of production that makes alcohol scarce, rather than the heat that is required to make alcohol. In the laboratory we can get as high as an 80 per cent yield, and it is not at all outside of the realm of possibility to increase the yields in commercial practice to such an extent that alcohol will compete with gasoline and we can leave some petroleum in the ground.

With reference to the shale-oil situation, I do not deny that it may be possible to produce shale oil that will compare favorably with present crude oils, but the best shale oil we can produce with our present knowledge is worse than the worst Mexican crude oil. There is very little light stuff in it. It is very difficult to refine it and obtain a fuel that the public will approve.

AUTOMOTIVE OIL ENGINE POSSIBILITIES

MR. GIBSON:—I am very glad that Mr. Ziesenheim is looking a long way ahead but, in discussing the disadvantages of the Diesel engine, I think that it would be better not to emphasize so much but put it up to the talent of automotive engineers to overcome such disadvantages as exist. First, it is not essential that a Diesel engine be so heavy because of its high compression. That is simply a popular thought. When we come to think of it, we are starting with a pressure of 500 lb. per sq. in., which, roughly, we do not exceed, we merely maintain it in the Diesel cycle. We know from Mr. Horning and other supporters of the detonation theory that we get a much higher pressure than 500 lb. per sq. in. in the ordinary internal-combustion engine. The Diesel engine has no shock at all; it is free from detonation troubles. If, then, we have only to deal with a pressure of about 500 lb. per sq. in., there is no reason the Diesel-engine cycle cannot be taken care of with engines just as light as we use today, except that a little more flywheel effect might be necessary.

Mr. Ziesenheim mentioned that the Diesel engine requires a high air-pressure in storage tanks, which is very dangerous. That is true as we know the matter at pres-

ent, but it is not true in regard to a proposed automotive engine. The high-pressure storage is for the purpose of starting the engine, but I have actually started a small Diesel engine without any pressure. It is a perfectly simple matter. We put a clutch between the flywheel and the crankshaft and rotated the flywheel up to a fairly high speed by some means such as an electric starter. The required energy for starting is stored in the flywheel and so long as a reasonably positive clutch is used between the crankshaft and the flywheel it is all right; I have done this in a perfectly satisfactory manner. If we adopt the attitude that such things can be done, I think we will progress more rapidly than if we assume too much that they cannot be done.

MR. GERNANDT:—There are five considerations to be dealt with in producing an automotive type of engine; the small high-speed engine, the metering of small quantities of fuel, the weight, the speed range and control and the type of fuel to be used. This subject has been my hobby for a number of years, in which I have built several types of high-compression oil-engine. I developed one at a time when weight was of secondary consideration, the idea being mainly to prove that small quantities of fuel can be metered and that the small type of engine can be built. Since then I developed a small engine of 2¾-in. bore. The cylinder-head was 5/16 in., the cylinder wall ¼ in., the piston-head 3/16 in. and the piston skirt 5/64-in. thick. The crankshaft was of liberal size, comparable with that of the standard automobile engine, and the flywheel weighed 94 lb. We were able to burn gasoline, kerosene, distillate, alcohol and fuel oil in this engine, without any change or adjustment. It was impossible to tell exactly what fuel was being used when it was running. The speed range was from 225 to 2250 r.p.m. and there was no misfiring whatever. The engine being of the two-cycle type, the matter of idling is worth considering. This engine has convinced me absolutely that the automobile engine can be built to use high-compression and oil as fuel.

MR. MOCK:—How many cylinders had the engine?

MR. GERNANDT:—It was a single-cylinder engine.

MR. MOCK:—How did you control the load?

MR. GERNANDT:—Merely by controlling the amount of fuel used.

MR. BREWER:—Has a multi-cylinder Hvid engine ever been built that gives equal power in each cylinder?

MR. ZIESENHEIM:—I think the engine of the Pittsburgh Filter & Engineering Co. is about the cleanest-cut four-cylinder Hvid engine that has been produced in this country. I think the results from it are comparable with those of a Diesel engine, so far as carrying full load on each cylinder is concerned. The Western Machinery Co. builds a gas-pressure-injection engine that is considered very satisfactory; the company has been in business for a number of years and there is no question that the engine can carry a full load uniformly distributed. I know that the Pittsburgh company's engine does deliver uniform power from each cylinder.

MR. BREWER:—That is a small engine, is it not?

MR. ZIESENHEIM:—It is a 100-hp. engine. Another small four-cylinder engine of the Hvid cycle is the Quayle engine built by the Commonwealth Motors Co., of Chicago, which has produced a number of them. The engine operates satisfactorily, but I do not know how well it distributes its load. The engines have been sold for driving generators; to drive a generator, unless uniform power is obtained from all of the cylinders, the engine would not be at all satisfactory.

MR. BREWER:—The Hvid engines on the oil-engined auxiliaries of the Shipping Board are mostly of the four-cylinder type. I believe they have great trouble in keeping the adjustment such that the four cylinders generate power equally. This is because the Hvid-engine fuel-control is extremely delicate. It is likely to become choked unless kept scrupulously clean.

MR. ZIESENHEIM:—One will never find two engineers who have the same mind as to how the Hvid engine operates. It is automatic. There are numerous influential factors, and each one takes its turn at being the dominant one. Any man who can get uniform results in operating a dozen different Hvid engines is a wonder. The principal disadvantage of the Hvid engine is that it is automatic and one cannot control it. The operation cycle cannot be controlled at all; moreover, if one changes the load conditions or the fuel, one must start all over; all that one has done in developing the engine seems not to have given any data that can be used to meet the changed conditions.

CHAIRMAN BERRY:—We all appreciate the fine qualities of the Diesel and the semi-Diesel engines and know that there is a definite field in which they will I think predominate. I feel, however, that the Otto-cycle-engine advocate should not be discouraged. Probably, in the ultimate solution of the engine problem, the dominant number of engines will operate on the Otto cycle.

The ultimate solution of the engine problem must be that producing the greatest amount of benefit from the petroleum that we have. We always must have a petroleum lubricant, because we know no substitute that can take any large part in replacing it. A considerable proportion of petroleum must be fractionated. A large part of the fractions will be gasoline and kerosene and we will use them in the Otto-cycle engine. In spite of the literature to the contrary, I feel that the thermal efficiency of the Otto-cycle engine, based on brake horsepower and considering the whole powerplant, will be just about as high as it is possible to get from the Diesel engine when the whole powerplant, including all the auxiliaries, is considered.

MILEAGE INCREASE AND ANTI-KNOCK MATERIALS

MR. MIDGLEY:—I believe that the greatest claim the Diesel-type or high-compression engine has for consideration is its high thermal efficiency. We can get just as high thermal efficiency from Otto-cycle engines if we increase the compression. I recently ran a 7 to 1 compression engine. The pressure was increased merely by decreasing the clearance volume by using longer, or higher, pistons. The comparative economies are shown in Table 2.

TABLE 2—COMPARATIVE FUEL ECONOMIES OF 4.1 TO 1 AND 7.0 TO 1 COMPRESSION ENGINES

Compression ratio	4.1 to 1	7.0 to 1
Fuel Economy at Full Load, lb. per hp-hr.	0.58	0.46
Fuel Economy at One-Quarter Load, lb. per hp-hr.	1.00	0.68
Relative Fuel Consumption when Idling	2	1

In addition, we have an increase in torque of 27 per cent, which can be transferred back and utilized as fuel economy on the road by decreasing the gear-ratio in the rear-axle. The sum total of these results is an 80-per cent increase in mileage. The question is simply how to get that 7 to 1 compression-ratio engine running on ordinary gasoline without having a bad cylinder knock. Since the above statement was made, road tests have proved the

80 per cent mileage-increase calculation to be low; it is more nearly a 125-per cent increase.

Table 3 is a comparison of the relative strengths of the different anti-knock materials. We have included water as an anti-knock material, although it is not truly one; almost everyone is familiar with water injection and can get an idea of the strength. Water takes 200 volumes compared to 1 volume of di-ethyl telluride.

TABLE 3—APPROXIMATE QUANTITIES OF VARIOUS ANTI-KNOCK MATERIALS REQUIRED TO GIVE THE SAME EFFECT

Substance	Volume	Weight	Molecules
Water	200.0	145	1500.0
Ethyl Iodide	35.0	50	60.0
Ortho-Toluidine	20.0	14	24.0
Iodine	2.0	7	5.0
Di-ethyl Selenide	2.5	2	2.5
Di-ethyl Telluride	1.0	1	1.0

CHAIRMAN BERRY:—Mr. Midgley brings out exactly the point that I wanted to have made. I feel that the Otto-cycle engine is capable of developing about the same efficiency as the Diesel, and it has the advantage of simplicity as well as a very much higher state of development at present.

DR. H. C. DICKINSON:—I wish to call attention to Fig. 1 of Mr. Ziesenheim's paper, which illustrates the distribution of the various components of petroleum. What we are interested in as an ultimate matter is getting the maximum of efficient transportation from the amount of fuel that is available. As automotive engineers, perhaps you are inclined to look at this figure and say that we are tapping 25 per cent of the total petroleum resources and that we are not getting hold of 75 per cent of them. Why should we not have the remainder? There are other sides to this question which must be considered. The use of fuel oil in marine transportation is only coming to be recognized in its true light of the saving in cargo space and increase in overall efficiency. Even the burning of fuel oil under boilers, which is certainly an inefficient use of our resources, is so much more efficient than burning coal that probably the shipping interests could afford to pay at present prices at least $10 per bbl. for crude oil. This all goes to show that, whatever happens, the automotive industry cannot look forward to absorbing all of the prospective petroleum supply by any means, because other economic interests can utilize it and can afford to pay as high or perhaps higher prices for it. Therefore, I believe that Mr. Midgley's discussion on the availability of alcohol is very much to the point. If we are to continue to operate automotive appliances on the present basis, we must find fuels for them, and there are two possible solutions. We may develop engines that will use a greater variety of fuel, which is, we all admit, a very important thing to do. No one wants to minimize its importance, but we may also develop fuels that can be used in the present type of engine. The ultimate solution should be the one of maximum efficiency. If the Diesel-engine designer can turn out an engine that competes favorably with the present Otto-cycle engine or with a more highly developed form, of this type he will get the business. The question of available fuel supply is perhaps not as simple as it appears.

MR. GIBSON:—All we are concerned with, I think, in comparing the possibilities of the Diesel and the Otto-cycle engine, is that we cannot utilize an engine that will for some time to come run at practically only one speed. I feel that the Diesel engine has a wide enough field in agricultural tractor work, or truck work, perhaps, but for the millions of automobiles that we are running now the ordinary man will not approve the Diesel engine.

MR. MOCK:—While we listen with interest to those who advocate the application of the Diesel or similar cycles to automotive purposes, I can see no particular advantage in blinding ourselves to the practical limitations that we all know exist. In the matter of fuel consumption the chief reason for the low efficiency of our passenger-car and truck engines is the fact that they operate so much of the time at part load, under conditions of low mechanical efficiency. If we examine the Diesel engine as to its part-load characteristics, I am very sure we will find that its slightly greater expansion-ratio efficiency will not compensate for the power lost in driving the various auxiliaries that it requires, and that actually its fuel consumption would be higher than that of present Otto-cycle engines. Further, everyone who has worked with carbureters knows that it is a practical impossibility to run a multi-cylinder engine smoothly at various loads and speeds with the fuel feeds individually regulated for each cylinder. Even if this could be done, I doubt very much whether a multi-cylinder engine could be made to fire at all smoothly at low loads by a reduction of the fuel feed. Consequently, the only high compression self-ignition engine that could be used would be the one-cylinder or limited load-range type of engine. Such engines would be tolerated only in motorboats or tractors, for which service they are not particularly adapted on account of the careful attention that is essential to their satisfactory operation.

MR. ZIESENHEIM:—A thing is never possible until it is done; that thought keeps the inventor struggling along. One question about the fuel characteristic shown in Fig. 2 of my paper is whether that will remain stationary? If the end-point of the fuel continues to rise and we must add heat to the fuel to vaporize it, we will have to continue to add more dope all the time, because the temperature at the end of compression will be higher. Referring to Fig. 4 of my paper, for a difference of 42 deg. initial air-temperature at 400 lb. per sq. in., say, we have over a 100-deg. change in temperature. This means that if we have an engine with a compression of 60 lb. per sq. in. and must heat the fuel 40 deg. above that normal compression temperature, we have as high an end-temperature as we would have with a compression of about 120 lb. per sq. in., which means that we must add a considerable amount of fuel dope.

MR. MIDGLEY:—It is not necessary to add much fuel dope.

MR. ZIESENHEIM:—The performance of the Diesel engine at part load is much superior to that of the Otto-cycle engine, particularly one of the throttling type. There can be no question of that; anyone who ever looked at comparative fuel curves can see it. I admit that the Diesel engine for automobile use is not an immediate possibility by any means, but its assumption of heavy-duty truck, tractor and marine work would certainly be of infinite benefit to the automobile industry and relieve the fuel situation considerably. From that standpoint alone it is worth developing.

ROBERTSON MATTHEWS:—The advocacy of the high-compression engine before the Society is in order, as is shown by the curves representing the fuel situation and the change in volatility of engine fuels in recent years. The elimination of the spark-ignition and carburetion elements of the Otto engine, as well as of the complex air-injection system of the Diesel engine, are much desired achievements, especially in connection with small high-speed engines. The large number of individuals and

laboratories who are striving to bring about this elimination is indicative of its great importance and leads to a desire for more published information of experiments and designs that have not been successful. There is much needless repetition of research and, as history shows, the difference between success and failure depends upon small variations of conditions. Careful and many-sided analyses of a supposed failure may point out the real path to success. Wise selection of narrations of such failures might tax our editors but, as has been said, there is a right sort of even nonsense.

With a scarcity of information respecting conditions that have not brought flexibility of operation with high thermal efficiency from small high-speed engines, there are many things that those of us attacking this solid-injection problem would like to hear about. Mr. Ziesenheim states that the average automotive engine operates at only one-third its rated load most of the time. Some test reports of large Diesel engines show remarkably flat fuel-economy curves with change of load. Can Mr. Ziesenheim give us any assurance that such flat fuel-economy curves can be obtained with small cylinders and with solid injection? We would like to know what the effect of slow speed, together with the large ratio of surface to volume of the small cylinder, may be upon the attainment of that temperature at the end of compression that is essential to cause compression ignition.

Has Mr. Ziesenheim found that at maximum load he can inject, under conditions favorable to freedom from detonation on the one hand and excessive maximum pressures or freedom from after-burning on the other, even light fuel oils in the short interval available with engines turning at from 2500 to 3000 r.p.m.? Has he considered the pressure in the injection system necessary for such intense operation?

I emphasize somewhat that a disadvantage of the medium-pressure engine in starting is the necessity for preheating an ignition surface. Has not the introduction of an electrically heated hot-spot, for starting only, overcome in large measure that disadvantage? Among the advantages of the high-compression engine is given "ease and simplicity of operation." Is that statement consistent with the disadvantage stated as "educational work necessary for the operation and servicing of a new type of engine"? Some of us fear that a gain in thermal efficiency will be at the expense of care in design and of both care and vigilance in operation.

Does Mr. Ziesenheim think that the improvement in the operation of the Pittsburgh Filter & Engineering Co.'s Brons-Hvid engine over the Sears-Roebuck Hvid engine may be because of the larger combustion-space, allowing more freedom of movement of the fuel spray without its coming into contact with cylinder walls and piston head? It would be valuable for some of us to know whether Mr. Ziesenheim has proved by his own research on small engines that 18 deg. before compression dead-center is a suitable angle for injection to begin, and to what range of revolutions per minute that value is applicable; whether 350-lb. per sq. in. pressure is sufficient for obtaining compression ignition in starting a cold cylinder of automotive size; and whether, with the pressures necessary for the injection of fuel in the short interval available with the rotative speeds of automotive engines, the elasticity of the fuel will be only 2 per cent.

The temperature curves of Fig. 4 in Mr. Ziesenheim's paper would be more valuable if the assumed initial pressure were stated and also the value of the exponent for the pressure-volume relation. Failure to state the conditions upon which data are based is a common weakness in much of our engineering literature, and most of us who write can be found guilty.

It would be of interest to hear from other investigators of the difficulties they have encountered with lapped and packed joints; also, about their experiences with valve systems that would not hold, and of their observations concerning the compressibility of the fuel itself. Perhaps someone may have learned how to abate the nuisance of air in the fuel feed-lines. What is the best filtering system that has been discovered for the fuel-feeding system?

Since most of the solid injection will eventually be for multi-cylinder engines, it may be worth while to compare a statement of Mr. Ziesenheim with a statement by G. Ure-Read in *The Engineer* (London) for Nov. 14, 1919. The former states

> With the injection-valve filled with fuel maintained at constant pressure and the fuel cam acting directly on the injection-valve, the injection action can be much more rapid than with the variable fuel-pressure generated by a cam and pump removed from the injection-valve.
>
> The constant fuel-pressure obviates trouble from the elasticity of the fuel and its containing system and also does not permit the entrapped air to expand and cause erratic injection.

The article in *The Engineer* states

> The cards were all taken from the same cylinder of a multi-cylinder engine. . . . .
>
> The engine was operated on the solid-injection principle, and so arranged that two methods of applying this system were possible; one where each cylinder has a separate pump discharging through an accumulator to its spray-valve, and another where the separate pumps discharge through their accumulators to a common pipe, and then to the spray-valves. . . . .
>
> In each group it will be noted that the revolutions per minute and the mean effective pressure are greater for the separate than for the combined system, notwithstanding the fact that the measured quantity of fuel per stroke was the same in both cases. The reason put forward for this result is that the capacity of the fuel system when each cylinder is fed separately is smaller in comparison with the capacity of the pump than when the combined system is used. Hence, the fuel pressure is greater when the spray-valve opens. . . . .
>
> In Figs. 2, 4 and 6 of this article, which show superimposed cards for the two methods, there is an appreciable difference in the point at which the pressure begins to rise, owing to combustion.

In presenting the possibilities and difficulties of applying high-compression and solid injection to the small high-speed engine, the Society is doing work of vital importance to the entire engineering profession and to the public.

P. L. SCOTT:—Mr. Ziesenheim's able presentation of the subject of automotive development of injection engines appeals to me as particularly apt at this time. There is much good opinion that the fuel situation will not compel us in this direction, but the problem has been before us for some years and has several good reasons for its appearance in addition to the aspect of great fuel conservation. If we are to accept injection as the most promising trend for automotive development, it is time that intensive study of the matter should be begun.

Heavy-oil engines for automotive purposes are often urged on the ground that they will burn the "heavy oils," which is only a half statement. Injection engines will burn whatever is most readily and cheaply available. This is something that no carbureting engine will do,

although it is possible to persuade many of them to include some range of fuels by adjustment and patience with increased trouble. Carburetion and electric ignition are more or less sensitive to variations in atmospheric and other conditions. Injection with compression ignition is not, and requires no field adjustment under any condition. Further, losses due to throttling are absent with the injection method of handling the fuel.

Mr. Ziesenheim points out that detonation can be overcome entirely by injection, with any fuel. It can be stated further that it is possible to control the combustion completely with injection. The process can be visualized as an intermittent torch introduced within the cylinder, the starting and stopping time of which is regulated and the flame of which is controlled to a nicety to obtain the best sort of chemical reaction. It seems to me that the matter of adaptability of injection systems to existing types of engine should be emphasized in such development. To make an injection system readily adaptable to present engines, the pressures must be kept low and a high degree of simplicity and reliability is essential.

Injection with spark ignition is mentioned. There also seems to be a possibility in the use of what Mr. Ziesenheim classifies as medium compressions, but with true Diesel operation. Such operation removes most of the objections given against medium-compression and puts it nearer the high-compression class. We have found it possible to secure reliable ignition, with one form of atomizing valve, at 250-lb. per sq. in. compression and have gone lower. The injection is timed 5 deg. ahead of dead-center with 300-lb. per sq. in. compression and continues through about 40 deg. for an engine running at 500 r.p.m. Ignition takes place within 3 deg. of the appearance of the spray, and engine cards together with spray diagrams show a fairly faithful following of the burn according to the rate of injection. Maximum brake mean effective pressures have been raised to over 90 lb. per sq. in. under favorable circumstances, although the exhaust is smoky. The engine is of the double-piston Junkers type, weighing 1370 lb. and developing 30 hp. normally at 500 r.p.m. The load has been increased to as high as 50 hp.

Mr. Ziesenheim concludes, broadly, that the variable-pressure system is suitable only for slow speed and rather "rough" constructions. The systems classed as variable pressure have so much to recommend them in mechanical simplicity and reliability that they deserve the fullest consideration and, in the light of experience, I would not concur entirely in this conclusion. It is true that elasticity or air-binding may upset the variable-pressure system. But the air-binding difficulty can be overcome by designing the pump to eliminate the air or liberated gas continuously, before it reaches the atomizing valve. Leakage is possibly not so important, because a few drops per minute is readily visible to the operator; whereas it takes several drops per injection to have a marked effect. Leakage can be held to a negligible quantity by reducing the number of joints and using satisfactory forms. Further, the trouble with pump-plunger leakage can be overcome by making the pump without a stuffing-box. After building several pumps without stuffing-boxes to handle from 0.1 to 0.2 cc. (0.0061 to 0.0122 cu. in.) maximum per stroke at pressures up to 10,000 lb. per sq. in., I am convinced that this is a good construction and certainly lasts much longer. The leakage past the plunger, in such pumps, can be reduced below a measurable quantity. With an indicating device for recording the start and stop and also the variations of the injection, it has been determined that it is possible to hold the timing within 1 deg. and the characteristics of injection within a few per cent, with an automatic valve, as regular performance.

The constant-pressure system has two disadvantages that are not mentioned; namely, that the valve-gear to obtain the very small lifts required, which are only a few thousandths of an inch, is a most refined piece of work, and wear or lost motion changes the timing as readily as air will throw the variable-pressure system off. Then the constant-pressure system increases the pump work by 100 to 200 per cent, which is an appreciable amount taken from the indicated horsepower. The mechanically operated valve also requires a high-pressure stuffing-box. Further, with mechanical-valve operation, it is impossible to obtain exceedingly minute valve-openings, with the consequent high degree of pulverization and very high velocities so important in securing good "penetration" of the spray. It is difficult to throw a finely pulverized quantity of oil across several inches of compressed air.

In the development on which some of the foregoing statements are based, the valve is automatic and injects at practically constant pressure, but the fuel supply is under variable pressure. The opening is produced automatically and is in the neighborhood of 0.0001 in. The resulting average velocities are about 10,000 ft. per sec. minimum and may reach 20,000 ft. per sec. An estimate of the velocity of a molecule of hydrogen under standard conditions is 5000 ft. per sec.; so, it will be noted that the momentum of the particles is in the neighborhood of the momentum of the molecules of a gas under high pressure. The mass of the molecule of any ordinary fuel is far greater than that of any of the constituents of air, and a particle of even very finely pulverized fuel contains a comparatively large number of molecules.

C. A. NORMAN:—Mr. Ziesenheim's paper is a remarkable contribution, on account of the thoroughness and impartiality with which injection-engine developments all over the world have been scrutinized and discussed. Such a scrutiny will help to avoid many errors, often costly. It will also furnish encouragement by showing that injection engines of the types simpler than the Diesel engine are now in operation in several parts of the world, and only await adaptation to automotive sizes and speeds. Such adaptation has in part already taken place in the case of the Junkers,[10] the Steinbecker,[11] the Brons-Hvid and the Blackstone engines, and in a perhaps somewhat more experimental way in the case of the Diesel engine itself. As most of these developments have occurred abroad, it is to be hoped that there will be no further delay in beginning similar developments in America. The work of E. A. Sperry[12] in this connection is most gratifying. Let us hope that Mr. Ziesenheim's experimental work will likewise meet with success.

R. M. HVID:—I have read with interest that part of the paper in which Mr. Ziesenheim makes a statement of the advantages and disadvantages of the Hvid engine as compared with other types. However, I am forced to the conclusion that he could have been in possession of only very superficial information regarding the Hvid engine and its developments here and abroad, and that he certainly has had no direct and general experience in its construction and design. Consequently, the conclusions he reaches with reference to it are inaccurate and misleading; they are not based on facts.

Mr. Ziesenheim states that the Brons-Hvid engine has been in existence nearly as long as the Diesel engine and

[10] See *Automotive Industries*, Oct. 7, 1920, p. 718.

[11] See *Automotive Industries*, March 3, 1921, p. 501; and *Power*, Oct. 12, 1920, p. 584.

[12] See THE JOURNAL, November, 1920, p. 454.

that it has achieved no success in Europe or America except as distributed by Sears Roebuck & Co. He states also that it is about 28 years since Doctor Diesel invented the Diesel engine. As a matter of fact it is 14 or 15 years since the first Brons engine was built. The first firm in Europe to build Brons engines had built from 200 to 250 engines up to 1911. Since then and in spite of the war several thousand engines of this type, from 4-hp. single-cylinder to 480-hp. six-cylinder, have been placed in service in Europe and other continents by the Brons Co., Holland; the Deutz Motorfabrik, Cologne; and Laurin & Clement, Bohemia. That these engines are giving universal satisfaction to users is indicated by the fact that, according to recent direct reports, orders are booked far in advance. I introduced the Hvid engine into this country and the first engines were built and placed in operation in 1913-1914. They can be obtained now from 21 different firms and the number constructed up to this time is several times 10,000. Other firms are under license and expect to have their engines ready for their trade soon.

Referring to Table 1 of Mr. Ziesenheim's paper, the conclusions reached from the data given in it are of very little value, as prices and ratings are only momentary, particularly in these times. That is well illustrated in this case by the fact that prices and ratings on the Hvid engines as stated in Table 1 were changed even before advance copies of the paper were received. The result of these changes is so great that instead of the Hvid engines costing an average of 84.1 per cent per b.hp. more than gasoline engines, as stated in Table 1, they cost only 20.5 per cent more; and, instead of costing $0.259 per lb., they cost only $0.177 per lb. In fact, the Hvid engines now cost a fraction less per pound than the gasoline engine.

The Sears Roebuck & Co. engine of the Hvid type, as well as the other builders' engines, are sold on a liberal guarantee covering economy, simplicity and reliability; and, while consideration has of course been given by the designer to the class of trade the engines are intended for, the fact remains that they will develop their full rated horsepower indefinitely, with the degree of regularity necessary for the service intended and with excellent fuel economy. Their success cannot, as Mr. Ziesenheim states, be attributed in part to almost exclusive use of kerosene as fuel, as this is not the case. Neither can their success be attributed in part to the elimination of crankcase dilution by the particular design adopted by Sears Roebuck & Co., because there is no crankcase dilution to eliminate in the Hvid engine as this term is generally understood, provided of course that the compression is maintained and the valves and the piston-rings are tight. This is perhaps best proved by the fact that several builders of vertical Hvid engines employ the common splash lubricating system for the cylinder and all the bearings in the crankcase, exclusively; one has done so for more than 10 years. The builders' general instruction to users is to renew the lubricating oil in the crankcase but once in three months, when the engine is used daily.

Excessive pressures in the cylinder of the Hvid engine do not occur except through misuse or when the valve-gear is out of adjustment. A compression-pressure of 425 to 480 lb. per sq. in. is recommended, depending on the size of engine and to some extent on the nature of the fuel oil. It has been found, however, that a wide range of fuel can be handled by the engine without any change in the compression-pressure. The maximum explosion-pressure in the cylinder is approximately 600 to 625 lb. per sq. in. It has not been found necessary, even in the large type of Hvid engine, to fit safety-valves to the cylinder-heads, such as are commonly fitted to Diesel engines. It has been found that if a Hvid engine is designed to withstand the same normal pressures as a similar size of Diesel engine, its strength is ample. This has been demonstrated in several thousand engines that have been in use for several years.

Regarding the fuel-cup, Mr. Ziesenheim seems to think this is a very difficult problem. As a matter of fact, it is very simple if we avail ourselves of the data that have been accumulated since these engines were first brought out. Even if such data were not available, a good engineer would easily find a suitable one after testing two or three fuel-cups, and certainly it would be a much easier task to design a proper fuel-cup for a Hvid engine than to design the injection-valve and its appurtenances for a Diesel engine. The fuel-cup is not such a delicate and sensitive part of the engine as Mr. Ziesenheim seems to think, and a fuel-cup decided on for a certain size of cylinder will handle a wide range of fuel, load and speed. Up to the present, cylinders of diameters ranging from 3 to 16 in. and with 33 intermediate sizes, with 42 different displacements, have been built and are in operation. Full data are at hand for the fuel-valves on all these engines, and engineers to whom such data are available should have little difficulty in designing the proper fuel-cup for almost any size of engine and for all ordinary conditions.

Whether the Hvid engine has the ideal conditions for pulverization of the fuel oil, I do not know, but I do know that the engines of the Hvid type will show excellent economy and maintain it with very little attention. On the larger sizes of engine, say from 60 to 80 hp., one firm guarantees a fuel consumption of 0.41 lb. of fuel oil per b.hp-hr. and even on very small engines a fuel consumption as low as 0.5 lb. per b.hp-hr. is easily obtainable. So far as I know, this is as good or better than has been obtained on the best engines of other types in similar sizes.

I fail to understand Mr. Ziesenheim's objection to the needle-valve governing. It is undoubtedly the simplest device that could be used, it has been found perfectly reliable at all times and any degree of regulation on the engine can be obtained with it. Mr. Ziesenheim states that the cutting-off of the fuel supply is not effective until after the result of several strokes have been discharged and burned and that consequently there is trouble. This is impossible unless the governor connections are defective, as the volume of the fuel oil in the small passage between the needle-point and fuel-valve is so small that it only contains a very small fraction of the amount of oil necessary for a full power stroke. This form of regulating the Hvid engine has been used for many years on single and multiple-cylinder engines, and there is no question about its reliability or that it is adequate for any service the engines might be put to, even if it does seem too elementary to some.

As to the possibility of a small quantity of fuel being drawn into the combustion chamber of the engine during the suction stroke, of which Mr. Ziesenheim speaks, it is possible that a very small quantity is drawn in, but if Mr. Ziesenheim had had more experience with this type of engine, he would have found that this enriching the air in the cylinder very slightly is of great benefit. The trouble that Mr. Ziesenheim thinks may come from this fact does not occur and, with reference to sticky pistons and piston rings, this trouble does not occur either if the piston is properly fitted in the first place and correctly

lubricated. Engines are known to have been in operation several years without requiring the pulling of the piston for cleaning or on account of loss in compression. Exhaust-valve troubles also are rare, as the combustion is clean and almost colorless.

Looking over the records for the engine built by the Pittsburgh Filter & Engineering Co., Oil City, Pa., I find that it was started for the first time on March 25, 1919, and that the testing period was finished Jan. 19, 1920, or 9½ months; at that time the engine was put in daily operation carrying the shop load. It has been doing its work since then to the satisfaction of the builder. From this record I find also that, during the testing period, less than two months was actually spent in testing and selecting the proper fuel-cups to meet the builder's requirements for this four-cylinder engine. This period is not excessive, in my opinion, considering the length of time it took to try out and decide on the other more or less standard features of the engine.

W. P. DEPPÉ:—I am somewhat astounded to note that not a single reference is made in these very able papers to the possibilities of homogeneous mixture-charges having the properties of gases in their superheated state before ignition. Combustibles in air must be transformed into gases in the superheated state before ignition and raised to the temperature of so-called ignition or combining points with oxygen before one can start the cycle of physical, chemical and electrochemical actions and reactions involved in this problem. Merely taking readings on tests of combustibles in air, and then taking similar readings on the products of combustion, certainly do not give any idea or measure of the transformations that are involved in the production, maintenance and delivery to the cylinders of a fuel charge in the modern internal-combustion engine. Further, all the authors seem to overlook the cycles involved in the fuel mixture when suddenly taking them out of partial vacuum and putting them under compression, as is done in the intake-pipes and cylinders of the modern vehicle engines. In addition, none of the authors seem to have considered at all the advantages of preventing altogether the so-called preignition under high compressions or preventing peak-pressures after ignition, due to the so-called autoignition or flame speeds producing so-called detonation, because of the heterogeneous mixtures before and after ignition, and heterogeneous flame speeds in different parts of the mixture charge after ignition.

There is no more wonderful mechanism in the hands of the public today than the four-stroke-cycle throttle-controlled internal-combustion engine operating on liquid fuel. It seems astounding to one contemplating seriously for one moment the fact that in wet-mixtures of fuel one is trying to perform all the functions of an oil refinery, city gas-works and the like, between the moment of ignition and that of actual power-pressure in the cylinder. By the correct use of superheat and the proper ratio of combustible, air and the products of combustion, under suitable operating conditions and limits, one can readily produce, maintain and deliver the fuel mixtures in such a way as to give all the properties of a homogeneous mixture of gases in the superheated state with preignition entirely eliminated and also auto-ignition and peak-pressure after ignition; further, with properly controlled combustion, one can give the qualities of throttle ability similar to those of the steam engine.

FIG. 15—TWO INDICATOR CARDS TAKEN FROM AN INTERNAL-COMBUSTION ENGINE

The Upper One Was Taken from a Six-Cylinder Engine Operated on a Controlled Combustion Superheated Basis While the Lower Shows the Controlled-Compression and Combustion Pressures without Doping the Fuel or Altering the Wet-Mixture Design

The upper portion of Fig. 15 is a Midgley curve showing the Spillman six-cylinder-engine indicator-card at 2200 r.p.m., which has all the characteristics of a steam-engine card, when operated on a controlled-combustion superheated basis. The lower portion of Fig. 14 exhibits also a Midgley card showing the controlled compression-pressures and controlled combustion-pressure without "doping" engine fuels, without altering wet-mixture design of engines, and doing nothing further than prepare the fuel properly and coordinate all the natural elements involved in this subject, and operating simultaneously and progressively in the complete cycle of events involved in this problem.

These conditions in superheat methods give very high mean effective pressure with somewhat lower maximum combustion-pressures than wet mixtures, and will enable the oil refiners to crack 80 to 90 per cent of all the crude oils in the world for suitable engine fuels with present commercially developed cracking methods of the continuous cycle of processes whenever the automotive industry simply decides to face the unfortunate conditions mentioned in the papers referred to and to improve them.

PRACTICE AND THEORY IN CLUTCH DESIGN

BY HERBERT CHASE

THE objects of this paper are to (*a*) set down in convenient form for reference purposes particulars concerning American and British practice in clutch design, (*b*) compare the advantages and disadvantages of various types of clutch and (*c*) give some notes on the theory of design without attempting comprehensive treatment of the numerous factors involved.

The descriptive portion deals almost entirely with clutches used on passenger cars and trucks, but some of the clutches described are applicable to other automotive uses. The notes on the theory of design apply in general to all automotive clutches.

The clutches considered are divided into the four general classes of cone, single-plate, multiple-disc and

shoe-or-band types, these being discussed at length and illustrated with drawings. After a consideration of the details of their design and a brief presentation of the subject of clutch brakes, the notes on the theory of clutch design are presented. An important feature of this paper is an elaborate tabulation of the specifications of various clutches.—[Printed in the July, 1921, issue of THE JOURNAL]

THE DISCUSSION

CHAIRMAN CRANE:—If we simply had to deal with a clutch intended to connect an engine with its transmission mechanism and to disconnect it when required, we would have a very simple problem. Unfortunately, however, the problem of temporary disconnection for the purpose of shifting gears brings in a question of spinning weights that militates against the best design of clutch for simple purposes of transmission. If that is given consideration, one will see just where the limitations of a cone clutch have been. Unfortunately, the larger the engine is or the greater the torque the engine is capable of delivering, the more difficult the problem becomes from the viewpoint of gearshifting, because the parts become heavier and heavier while the speed variations required to be accomplished in gearshifting remain the same. A cone clutch of small diameter can take care of such conditions and still provide sufficient surface with an engine of small torque capacity. With an engine of large torque capacity, it cannot do so.

One very well known foreign car uses a cone clutch, and I am informed that it is impossible to shift from high gear to the next lower gear at any high speed without resorting to what is called double-clutching; withdrawing the clutch, shifting the gear into neutral, allowing the clutch to reengage and speeding up the engine to speed up the clutch mechanism and the lay shaft in the gear box, and throwing in the gear after again disengaging the clutch. An expert operator can do this and make a very good showing with that type of clutch, but the average driver cannot do it at all. He is forced to a very noisy gearshift, which also results in excessive strains on the gear teeth, or else he cannot expect to shift down on his gears except at very moderate speeds, which seriously interferes with the efficient driving of a car.

I have noticed a tendency to misunderstand the function of the clutch brake in gearshifting. The clutch brake is of use in shifting from a lower to a higher speed because at that time a slowing down of the spinning parts is required; but it works entirely against the operation in shifting from a higher to a lower speed, and this is the shift that is most difficult to make and occurs usually at a critical time on a hill when it is most desirable to maintain the motion of the car. The only cure to accomplish good gearshifting under those conditions is the light spinning weight. It is a very difficult problem on a big engine to strike the correct compromise.

A clutch of very small diameter appealed to me very strongly about a year ago until after I made a thorough study of it. I found that, due to the small diameter and therefore to the small radius with which to absorb the torque, it presented an almost impossible problem, and that one is practically forced into using a friction surface of fairly large diameter to do the work.

As a matter of interest, there is a clutch installed on one car, experimentally, that uses a disc 1/16 in. thick as a spinning member. I think it is not a commercial proposition, but in careful hands it operates extremely well. With the lubrication that I think it deserves, the single-plate clutch has resulted in absolute immunity from wear on the friction surfaces outside of the plate, in my experience. An experience of 10 years and upward of 100,000 miles of service have not resulted in the replacement of a single fabric facing in clutches of that type, the reason being that the lubrication of the fabric is sufficient to replace the natural loss of binder due to the heat conditions of operation and maintain the fabric in practically its original condition. A dry asbestos fabric without any binder is about the flimsiest piece of woven material that has ever been seen. There is no real continuity to the fibers and the thing cannot stand. With a proper binder it is an extremely durable material.

W. E. LAY:—Another contradictory thing about a clutch is that when on high gear or in hard pulling one wants it to stick but, when trying to start the car, since the car is still at rest and the engine will not pull at practically zero speed, the engine must be running when the car is standing still and there must be slipping. That is true also when changing gears.

CHAIRMAN CRANE:—That part is obtained very simply by the variation in spring-pressure obtained through the foot-pedal. The worst difficulty is that it is necessary to have the slipping friction sufficient to stall the engine and not the standing friction alone. That difficulty has been experienced in certain forms of the multiple-disc clutch; the friction of the discs on the splines has been sufficiently great that, if the engine is speeded up and the clutch allowed to begin engagement, the full spring-pressure is not obtained on all the discs. It has been obtained on the first disc but, due to friction on the splines, each succeeding disc has a little less pressure on it. Before the clutch is actually engaged by reducing the throttle-opening so as to relieve the torque momentarily, the clutch does not take hold.

B. B. BACHMAN:—Will Mr. Chase elaborate further his reference to gear teeth? As I understand it, gear teeth are purely the internal and external form of tooth in which line contact is, of course, obtained. But there are methods of generating what are approximately tooth forms that have full line or full surface contact, and to all intents and purposes are what he mentions as keys. Another item that is an important factor in clutch design is the matter of the bearing surface between the plates and the driving means, the range of bearing pressures. I am sorry that Mr. Chase did not have such data to present. If we had the figures on that subject, I think that the variation in the pressure allowed on the splines of driving plates would be found to vary so widely as to be startling.

Another point is the question of the ball bearing. It has been my experience that the use of a ball pilot-bearing is in some instances beset with difficulties, because it is almost utterly impossible to get lubricant to it; furthermore, in a number of forms of clutch, what lubricant does reach it contains a certain amount of road dust or rubbings from the clutch surfaces that the lubricant picks up and holds and possibly more trouble is caused than if there were no lubrication. I do not mean to say that the plain bearing is entirely free from difficulties of that sort, but I do believe that there is a field for investigation and further development of a bearing that is so thoroughly hidden that it is not accessible and cannot be seen without much dismantling.

MR. MOSKOVICS:—An interesting type of clutch that Mr. Chase has not described was known as the Langdon and was used in the Mercedes models. It has the one feature of being practically a locked type of clutch when it was finally engaged. It has good slippage and is very light. I think some cars are still using that type of clutch

in Europe. There are difficulties with regard to its practical production, but that should not prevent us from finding out about it; eventually, we may learn how to make it at lower cost.

CHAIRMAN CRANE:—We overhauled a 1906 Mercedes which had that type of clutch. We called it a wind-up clutch. It consisted of a very small-diameter hardened drum and a hardened square-section coiled spring. The operation of the clutch was not particularly simple, especially in city usage. It was apt to grab and we were warned to be extremely careful about slipping it for any length of time, due to the rapid wear. The gearshifting on that car was certainly a joy. One could snap the lever with one finger at 30 m.p.h. and go from third to fourth speed without a sound from the gearbox. But I doubt if the clutch would have been satisfactory as a commercial proposition. The surfaces were so small and the pressures so high that it could not withstand the kind of slipping that exists in the rough everyday service of the average owner and driver in this country.

JOHN MCGEORGE:—That same clutch was used on locomotive cranes built by the Browning Co. in Cleveland; it withstood some of the hardest and roughest usage to which it could be put. I know of no rougher clutch usage than is found in locomotive cranes. In a much larger and heavier form it also has had rough heavy usage in the rolling mills of England.

HERBERT CHASE:—In the clutch of small diameter, it is true, as Mr. Crane has said, that the torque is high at small radius, but it is practicable, especially in the multiple-disc type, to maintain a small diameter and get the advantages of low spinning weight and decreased inertia of the driven member while still securing ample capacity with moderate spring-pressures.

Mr. Bachman mentioned the matter of gear-teeth contour and the area of tooth bearing surface. With a proper tooth-contour the contact area is the same as with keys or splines.

The matter of pressures on splines is a very important one and I regret that data were not collected in this regard. It is a distinct advantage to avoid the use of splines at a small diameter. This can be done in certain types of clutch, particularly in the gear-tooth and key type of multiple-disc clutches described.

The pilot bearing deserves much study. There is a wide diversity of practice in applications; some prefer the ball bearing, some a plain bearing, and some a so-called oilless type. They are all mentioned in my paper. In some designs the British arrange to lubricate the pilot bearing by pressure, with oil in the hollow type of crankshaft, putting a plug of wicking or similar material in the hole connecting the two to prevent too rapid a flow. The difficulty, however, is that over-lubrication may result and oil reach the friction face, causing slippage; or that the oil duct will become filled with sediment and the oil supply fail.

The only reason I did not mention the Mercedes clutch along with a number of other types that have been used by a few makers is the fact that it is not used extensively to-day. It has some advantages, but it has the disadvantage that Mr. Crane mentioned of grabbing unless very carefully handled. The several disadvantages of the disc type in oil are set forth. The primary disadvantage is the lower coefficient of friction.

D. E. GAMBLE:—Mr. Chase is to be congratulated on this interesting and timely treatise on clutch design, for it is generally admitted that this unit has not received the attention that the other essential units of motor cars have enjoyed. On behalf of the single-plate clutch I will call attention to a few points that may have been overlooked. First, as to the objection to a decrease in the spring-pressure when wear takes place at facings, it is possible to compensate for this decrease by proper design of the lever or toggle devices. In the Borg & Beck clutch the actual plate-pressure is greater when the sleeve is in the inner position than when the clutch is adjusted to the proper sleeve position. This is due to the fact that the mechanical advantage of toggles is approximately 10 at the original set-up position and 13 when the sleeve is worn in ¼ in. A great advantage of the single-plate clutch is its ability to dissipate rapidly the heat caused by friction. The use of the flywheel proper and a rather heavy cast thrust-ring as friction surfaces is ideal for conductivity and dissipation and, in addition, it is common practice to use a moderate section of cast iron in the driven plate. This plate is cast integrally with its hub and therefore there is much more surface and mass available for dissipation than is possible in the very thin stamped steel plates necessary in multiple-disc construction. After a short period of slipping at high torque the plates of a multiple-disc clutch are generally burned and warped beyond repair; whereas the cast-iron disc in a single-plate clutch under the same conditions will withstand considerably more abuse. Of course, such abuse is not recommended in any clutch, for ample gear-reduction is available in all modern vehicles for the proper increase of torque at the wheels.

This matter of heat dissipation is of extreme importance, for it affects vitally the wear of facings or, more properly speaking, the reduction in thickness of facing. We have found in conducting facing tests that under ideal conditions such as ample torque capacity, moderate unit-pressure and minimum slip during engagement, there is practically no wear on the facings of either the woven or molded type of asbestos material. However, when a clutch of any type is slipped at high torque over extended periods, the facings are rapidly reduced in thickness, due, we firmly believe, to destruction by heat rather than abrasion. This theory is supported somewhat by service reports from many manufacturers to the effect that some customers have obtained service in excess of 20,000 miles without clutch adjustment, whereas other customers require clutch adjustment every few hundred miles. It is hardly probable that the heat generated during the periods of slip approaches the temperature of 1500 deg. fahr. necessary to dehydrate the asbestos, but it is likely that a surface temperature of 800 to 1000 deg. fahr. is often obtained and this tends to destroy the binder used in the manufacture of all of these asbestos products.

It is extremely unfortunate that many applications of single-plate clutches have not received proper attention in the matter of unit-pressure. There is of course a great temptation to select the smallest and cheapest clutch that will transmit the required torque satisfactorily, and the single-plate clutch, on account of the very high pressure made possible by the multiplying levers or toggles, is capable of transmitting an enormous torque with a comparatively small diameter. Due consideration must always be given the service required of the vehicle, its weight, gear-reduction and the frequency of clutch engagements.

Smoothness of action is in my opinion very largely a matter of accurate production and proper care in assembling to insure proper alignment of surfaces. It is obvious that the buyer is now much more critical as to performance than formerly, and I believe all clutch manufacturers realize that the quality of workmanship on

clutch parts must be brought somewhere near that maintained in the case of transmissions and axles.

ARTHUR B. BROWNE:—A study of the various designs of the four types of clutch shown by Mr. Chase will convince anyone that the same engineering ability that has been exercised in other units of the motor car has not been applied to this important unit. The Society should be congratulated on placing upon its records the valuable collection of data contained in this paper, which preserves in convenient form for ready reference the essential details to enable the car designer to select the unit best suited to his individual requirements.

Heretofore, first cost has been of greater consideration in the selection of clutches than has been the case with many other units, and yet there is no unit of motor-car construction with which the driver-owner comes into more intimate personal contact, nor which can make or mar the reputation of the manufacturer more quickly or more effectively than the clutch. The modern motor car owes its popularity to its ease and smoothness of operation; consequently it is the more disconcerting to have one's back suddenly thrown against the cushions by a harsh engagement of the clutch, or, on the other hand, to have a racing engine give warning on the first piece of sandy road that a visit to the next garage is necessary for clutch adjustment. The sale of many a car has gone to a competitor because of the difficulty of gear-shifting and many a stiff clutch-spring has resulted in just complaint on the part of the truck driver, with its certain reaction on the owner and manufacturer. The reasons for all these defects, and their remedies, are clearly indicated in Mr. Chase's paper and it is hoped and believed that more serious practical consideration will be given to the little understood and much abused clutch, as a result of its publication.

The fact that the multiple-disc clutch is used almost exclusively on the better grade of cars and trucks, at least in this country, is a practical argument in favor of the performance of this type that it is difficult to refute. The popularity of other types seems to have, as a sole basis, their cheapness of production and their availability as a market product. It would seem possible, in view of the data contained in Mr. Chase's paper, to design the multiple-disc construction so that, by production methods, its cost would at least minimize the advantage in this respect now enjoyed by the other types. In such design it would be advantageous to keep the mean radius as short as possible. Not only does this save weight of materials entering into the construction, with a consequent saving of cost, but, what is even more important, the radius of gyration is shorter and the inertia effects on disengagement are minimized, while, as Mr. Chase has mentioned, the wear on the smaller facings is actually less, due to the decreased linear speed during engagement. While it is true that the smaller facings are carrying a heavier load at the shorter radius, it must be remembered that this load is or should be carried without slip and that practically no wear occurs while the clutch is engaged but only at moments of partial engagement. The action of the shorter radius in reducing inertia effects is striking. With a reasonably short radius of gyration the use of a clutch brake is wholly unnecessary and without any brake whatever there is a freedom of gearshifting which must be experienced to be appreciated.

The formula given in the paper indicates that this desirable short radius can be secured only by multiple-disc construction, if due strength is to be maintained in the driven member of the clutch. With a given radius it is necessary only to have a sufficient number of discs to carry the maximum torque of the engine safely. With this number of discs it will be recognized speedily that a softness of engagement has been secured that is not commonly shared by other types of clutch. Adding a greater number of plates seems, in my experience, not to affect the softness of engagement materially, but the resulting increase of frictional area does add to the life of the facings or decrease normal wear. The proper number of plates therefore is the number necessary to carry the load safely, plus such other discs as the manufacturer is willing to pay for to give his product a longer life without replacement of the facings. It should be stated in this connection that, with modern clutch-facings of proper frictional capacity in sufficient number to carry the load with the proper spring-pressure correctly applied, the normal life of the clutch facings is more than sufficient to carry the vehicle past the period of otherwise necessary overhaul. None of the foregoing factors can, however, be minimized in its relation to the others, nor can the balance between them be disturbed without seriously diminishing the life of the facings themselves.

Mr. Bachman has raised one question that may well exercise the ingenuity of the members. This is the lubrication of the clutch pilot-bearing. In a somewhat wide experience I have never seen any adequate provision made for the lubrication of this bearing. Mr. Chase's statement that it does not need much lubrication does not detract from the problem; in reality it adds to it, because, while it is true that it does not need *much* lubrication, it does need *some* constantly, and it seldom gets any except that which the thoughtful assembler provides. A hollow clutch-shaft, or stem gear, is worse than useless for the lubrication of this bearing. It clogs after the first few miles. Pressure feed from the engine is apt to provide too much lubrication with resulting spattering over the clutch facings. I lean to the oilless type of bearing, but would welcome a more effective device for this, the most neglected bearing in all the chassis.

L. H. POMEROY:—Mr. Chase is in error when he states that clutches of the type shown in Fig. 18 of his paper, as used on the Vauxhall car, need to be run in oil. The Vauxhall clutch has been in successful use since 1910, the only lubricant used being powdered graphite. For this reason the somewhat formidable list of disadvantages of this type of clutch presented by Mr. Chase do not exist.

An additional advantage of the metal-to-metal disc clutch is that no provision need be made for adjustments of the clutch spring-pressure and, as the total wear after prolonged use is negligible, there is also no necessity for providing any adjustment for the position of the clutch-pedal itself.

MR. CHASE:—The reference to the Vauxhall clutch as being one which runs in oil is evidently in error. It is true, however, that metal-to-metal clutches require lubrication, graphite being used in place of oil in this case, with consequent reduction in the coefficient of friction. For this reason a greater number of plates is required as compared with the fabric-faced discs to carry a given torque with a given spring-pressure and size of disc. The cost and the spinning weight are therefore higher; hence, the metal-to-metal type is not without disadvantages. In some other makes of metal-to-metal clutch oil is used for lubrication, and in practically every case they are subject to the other disadvantages cited in my paper as resulting from this practice.

LUBRICATION

BY C. W. STRATFORD

LUBRICATION problems and the manufacture of lubricating oils are discussed in the paper. An outline is presented of the principles of lubrication; the sources, properties and manufacture of available internal-combustion-engine lubricating-oils; and similar factors regarding greases. Consideration is then given to these subjects.

Friction and its elimination are commented upon in a general manner, inclusive of comment on the best working temperatures for lubricants, blending oils and removing moisture. The various systems of lubrication are discussed; a classification of crude petroleum is made and the refining processes of the various grades of lubricating oils are outlined. Other subjects considered include the proper choice of lubricants, serviceability, available American engine lubricants, filtering and crankcase dilution. The composition and characteristics of the greases are reviewed briefly.—[To be printed in an early issue of THE JOURNAL]

THE DISCUSSION

CHAIRMAN CRANE:—I think the difference between splash and forced-feed lubrication is not so much in lubricating effect as in cooling effect. It is evident that a crankshaft running at say 2000 r.p.m. develops such great centrifugal forces that oil squirted or thrown at the crankshaft probably will not touch it at all, and that we will get but a very small amount of cooling by splash lubrication of the shaft and its bearings, especially those of the connecting-rod. In the type in which the oil is forced in large quantities into the crankshaft and emerges through the various bearings we have a regular source of supply to maintain the oil-film that is of course necessary, but, equally important, we have a very large source of supply to carry off heat.

We have found that the slow-running engine with fairly heavy duty can run satisfactorily on splash lubrication if the bearings are sufficiently large. The high-speed heavy-duty engine, however, has absolutely required lubrication by pressure to assure successful operation. This is especially true in airplane engines.

The thing of first importance in the installation is to give the oil a chance to settle as it comes from the bearings. Fortunately, there is a very large surface in the bottom half of the crankcase over which the oil is flowing at a rather slow speed and, as it flows down these walls, there is a natural tendency for the heavier solid particles to sink to the bottom. A very shallow trap at the bottom will catch these particles, if the suction inlet for the oil-pump is not carried to the bottom; bringing this point ⅜ or ½ in. above the bottom of the lower half of the crankcase is sufficient to provide for the settling feature. The use of large screens for the oil coming from the bearings is almost out of the question, due to the rapid clogging of a screen of sufficient fineness. On the other hand, a rather small screen of even 70 mesh, which we have used for a long time, placing it between the oil-pump and the bearings, will catch many small particles that have not been caught in the settling. A certain portion of the impurities is light in weight, such as sand and particles from the aluminum castings, and some lint or the like always comes through an engine that has been overhauled. Such materials will be caught in a fine-mesh filter without interfering with the flow of the oil produced by the power of the oil-pump.

J. N. HEALD:—Very few people appreciate adequately the tremendous waste of lubricating oil in an automotive engine. The amount of oil used is tremendous, in comparison with stationary steam-engine practice. In fact, a high authority on this subject has stated that automotive engineers should be concerned more with regard to the future supply of lubricating oil than of gasoline, and that the best engineering practice should be to give more attention to the conservation of the lubricating oil.

One source of loss of oil in an engine is the pumping of the oil up into the combustion-chamber, where it is burned without any useful effect. In fact, it simply fills the combustion-chamber with carbon and soot, fouls the spark-plugs and requires frequent scraping out and cleaning. Another source of loss is the dilution of the oil in the crankcase by gasoline passing down by the piston-rings, thus rendering the oil valueless for lubricating purposes.

These two sources of loss are due largely to poor machining and fitting of cylinders and rings. While the cylinder bores in the better grades of car are finished by grinding, thousands of engines for the less expensive cars are finished by simply boring and reaming. It is these latter cylinders that give the most trouble with respect to the loss of oil. The grinding process produces a hole that is almost absolutely round and straight; it has a highly finished surface, piston rings can be fitted so perfectly to such cylinders that pumping up oil is eliminated almost entirely and the leakage of gasoline past the piston-rings and into the crankcase is avoided. Rings also can be fitted with less initial tension, which cuts down the resistance to their motion, and therefore reduces the internal friction of the engine. It should be obvious that the grinding process, which eliminates two very troublesome sources of loss in the problem of lubrication, should be given more careful attention by many manufacturers.

W. G. WALL:—Is it possible, in refining lubricating oil, to eliminate all the free carbon? Is it desirable to do so? We know that when a crankshaft equipped for forced-feed lubrication revolves rapidly there will be a deposit. What proportion of that deposit is free carbon and also carbon washed from the cylinder walls, and what proportion is carbon due to the breaking down of the oil? Is the breaking down of the oil due entirely to the heat or partly to the centrifugal force of the crankshaft?

R. P. LAY:—Several solid and liquid preparations are being sold which manufacturers claim will remove carbon from the engine cylinders and pistons. Do such preparations have any effect on the carbon? Is there any way to remove carbon except to dismantle the engine and scrape it out?

MR. ZIESENHEIM:—The function of a lubricant is to prevent metal-to-metal contact of sliding surfaces by the shearing of an oil-film separating them. What gives to a lubricant the property of oiliness or unctuousness, is not entirely understood. Some writers maintain that the colloidal matter of the lubricant unites firmly, by a quasi-chemical action, with the bearing surfaces, and that it is the shear or sliding action of this colloidal matter that gives lubrication. What is Mr. Stratford's opinion of this theory?

C. W. STRATFORD:—As to whether it is possible to remove free carbon, there is practically no free carbon in finished engine oils. If an oil is distilled as in the

graphitic carbon residue test, at the end of the test there will be a certain amount of free carbon, but that carbon is due to its decomposition. There is no free carbon that one can filter out; the compounds that are filtered out are color-bearing compounds removable by Fuller's earth or Death Valley clay; they appear to be carbonaceous matter or peculiar chemical compounds.

In regard to the percentage of carbon in the carbonaceous sediment occurring in the crankcases of engines, I have never found it in excess of 2 per cent in hundreds of analyses. The 2-per cent case was due to very thin piston-heads; the oil was carbonized by being thrown up underneath and formed a cake, and that cake dropped down. Usually the so-called carbon deposit in the crankcase would be less than 1 per cent.

Concerning the carbon and the carbon deposit above the pistons, there also the percentage is very low, except where carbonization occurs due to using too rich a mixture, the carbon coming from the fuel and not the oil.

MR. WALL:—Is the deposit on the crankshaft, not the crankcase, due in any way to the centrifugal force of the crankshaft?

MR. STRATFORD:—In forced-feed systems like that used on the Liberty and some other engines, where there is a deposit on the crankshaft it is certainly due to centrifugal force, the crankshaft acting simply as a centrifuge, precipitating a sediment. I have never made an analysis of this deposit, but I believe that it consists of all the contaminating elements contained in crankcase oil at present.

OIL SPECIFICATION

W. M. BRITTON:—I have always believed that it might be possible to specify exactly what is required in lubricating oil. Oil representatives always state that it is aboslutely impossible to specify a lubricating oil in exact terms, and that one must simply follow their recommendations regarding oils and depend on their reputation. It has seemed to me that there are several vital qualities connected with a lubricating oil that could be expressed definitely. For instance, the viscosity of the oil at the particular temperature at which it will be used is vital. That can certainly be expressed. Probably the lowest temperature at which the oil will be used is fairly well known, and the cold test of the oil at that lowest temperature is certainly of importance. That can undoubtedly be expressed, for it is a well known property. The flash-point and the fire-point may or may not be of value in such a specification.

Another vital quality is the wearing property of the oil. The breaking down of the oil may be due to its actual mechanical use, or to the disintegration of the oil by the high temperature. Can the specific duty that the oil must perform be expressed for any particular purpose? It appears to me that tests could be made of the oil in a particular engine, and the effect of such use determined. The results of such tests could then be embodied in specifications for the oil that should be purchased.

There is also the question of paraffin-base and asphaltic-base oils. The producer of the asphaltic-base oil will say that if a satisfactory performance of oil is wanted in the engine, one must use asphaltic-base oil because the carbon that accumulates in the combustion-chamber is of a soft nature and does not solidify with the dirt that accumulates there and cause preignition. The refiner of the paraffin-base oil will say that one must use paraffin-base oil because the asphaltic-base oil will not stand up in the engine, disintegrates rapidly and is not a satisfactory oil.

MR. STRATFORD:—A flash test is usually made in the Cleveland open cup on lubricating oils and is an indication of the volatile products contained in the oil. By definition the flash point is the temperature at which the vapors arising from the oil will just ignite without igniting the oil. By making an extended study of the volatility of engine oils and distilling them dry under high vacuum, I found to my surprise that the flash-point of oils does not necessarily indicate the percentage of volatile products contained therein, as one would expect. It is my opinion that this is one line of research that merits considerable additional work. I am now setting up an outfit to continue the work that I have done, distilling under a high vacuum, also dry and with superheated steam.

HEAT TEST OF OIL

As to the possibility of writing into the specifications some test by which one can guarantee serviceability of the oil, I know of only one test that I think would serve in this way, and that is a very simple test called a heat test. The chemist of an oil company told me that some oils became black when heated. I used two flasks and what is known as an acidulated oil; also, as a second sample, I used a highly filtered spindle oil. I put them in the two flasks, put one on an electric hot-plate, raised the temperature about 500 deg. Fahr. and held it there for 10 to 15 min. I found that the acidulated oil broke up or turned black because of sulphuric acid that was freed on account of the heat decomposition immediately attacked the hot oil and precipitated a black sludge. I continued experimenting with this simple test and found that when finished engine oils are put in a small nickel-plated cup about 1½ in. in diameter and 1½ in. high, filled to about ¼ in. of the top, put on a hot-plate with a thermometer and the temperature of the oil raised to 550 deg. fahr., held there for 10 min. and then allowed to cool, there is an incrustation on the inside of the cup immediately above the surface of the oil. It is rather soft, as Mr. Britton mentioned, and it is carbonaceous regardless of whether the test is made on paraffin-base or asphaltic-base oils. The character of the carbonaceous deposits is very similar. There is also a formation of a gum or resin on the outside of the cup. At the high temperature the oil creeps up to the top of the cup and flows over. It undergoes oxidation and forms a gum or resin that is entirely insoluble in any petroleum product and soluble only in hot caustic alkali.

From long use of that method I think I am able to determine in the shortest possible time whether an oil is a good engine oil, but I do not know how to describe just how to do so. A poor engine oil will turn black when subjected to the test and, when held against the rays of the sunlight, appears to be of a very high robin's-egg-blue color. If it is a good oil, it will have an amber tone. When poured out of the cup, a poor oil will always leave a sediment; but a good oil will not. The appearance of the film on the empty warm cup is another means of judgment. The amount of evaporation that occurs during the heating of 10 min. duration is a good, although not exact, indication of the volatility of the oil. Anyone can make this test and in a very short time, I think, become an excellent judge of the quality of engine oils by using it only. It is very easy to determine the viscosity and, since it is one of the most important factors of lubrication, we have a standardized method of test for it. Before it will be possible to write into specifications facts that absolutely determine the properties fixing the quality of oils, we shall have to standardize methods. Much re-

search work must be done before a standardization of methods for testing the oils will be possible.

A carbonization oven gives an excellent indication of what will happen after an oil is in use in an engine. The equipment is rather delicate. By using an oxidation oven I was able to distinguish the difference between good and bad oils in 4 or 5 hr. I could check the results within less than 2 per cent.

THE MUTUAL ADAPTATION OF THE MOTOR TRUCK AND THE HIGHWAY

BY A. T. GOLDBECK

THE aim of this paper is to stimulate thought on how to accomplish the greatest possible economy in transportation over highways. The fundamental thought is that the expense of highway transportation involves a large number of items that can be grouped into those directly concerned with motor-truck operation and those involving the highway, and that highways and motor vehicles should be adapted mutually so that the greatest economy of transportation will result.

Urging that the automotive and the road engineer cooperate in gathering information that will give them a more definite basis upon which to design the truck and the road, the present rapid destruction of roads is discussed and remedial measures suggested. The designing of motor trucks to conserve the roads is treated at some length and a plea for cooperation between the society and the highway officials is made. [Printed in the August, 1921, issue of THE JOURNAL]

THE DISCUSSION

RUSSELL HOOPES:—In the destruction of the road, what is the relative effect of different amounts of unsprung weight of the wheels and the axle of vehicles?

A. T. GOLDBECK:—There is a somewhat decreased impact on the road surface due to light unsprung weight as compared with heavy unsprung weight. This is, however, not the most important effect; it is overshadowed by variations in the tire equipment. We may get variations in impact due to tire equipment of as much as 200 per cent. The variation in impact due to unsprung weight does not nearly approach that.

MR. BACHMAN:—Motor trucks have been developed to meet road conditions as they were found. As they have existed with regard to surface, grading and the like, road conditions have been such as to require a certain type of construction for the movement of certain loads, which represents weight of a certain quantity. Given a different type of road construction, with a material reduction in the gradient and an improvement in the surface, an entirely different form of construction that will give another definite quantity of weight for the vehicle can undoubtedly be used. The ultimate purpose of transportation is not to create a vehicle so much as it is to move merchandise. The ideal vehicle would be one that was entirely negative and did not exist; one could move merchandise by utilizing some invisible force. How we are to solve this proposition is what Mr. Goldbeck is asking, and I think the Society also is vitally interested. Road builders have the problem of constructing roads for vehicles that have been created for various conditions and will under improved conditions be capable, from power and structural standpoints, of carrying considerably greater loads than they are able to carry under present conditions. On the other hand, the builder of vehicles is forced to take into consideration the road conditions that exist at present as regards the weight and power of the vehicle.

One of the big factors in the fuel problem is the road problem. There are remarkable differences in the ton-mileage per gallon of fuel with different road conditions. I have driven the same truck over two different roads about 30 miles long in the vicinity of our factory; one has a gradient close to 18 per cent on one section; the other is an improved highway of excellent construction and has a gradient of probably not over 6 or 7 per cent. The latter is not a low grade from a railroad standpoint and probably not an impossible grade from a highway standpoint. The difference in operation, in ton-miles per gallon, over those two types of road is very remarkable. We must consider the whole highway problem from both the highway and the vehicle standpoints and the highway and the automotive engineers must work together.

PROFESSOR WILSON:—Is it a fact that, while the use of pneumatic tires instead of solid tires reduces impact on the road surface, it does not give the distribution of load necessary to prevent a breaking down of the sub-structure, and that the latter can be prevented only by using more wheels per vehicle?

MR. GOLDBECK:—The pneumatic tire is practicable only up to a certain size and is capable of carrying only a certain maximum load. It does not distribute the load sufficiently over the road surface; its area of distribution is not greatly different from that of a solid tire, from the standpoint of the structural design of the road. So, although the pneumatic tire does greatly reduce the impact and would do a tremendous amount of good if we used it on the large sizes of present and future trucks, it is necessary to at least consider the matter of using more wheels per vehicle. I advocate that we seriously consider the possibility of doing that.

H. W. SLAUSON:—Has Mr. Goldbeck made any tests regarding the length or the type of spring suspension used on the trucks and the effect on the impact? He has stated that the amount of unsprung weight makes relatively little difference. Do the type and design of the spring make as little difference?

MR. GOLDBECK:—We have made no tests regarding the spring suspension. That probably will be taken up this year.

MR. SPERRY:—It is a fact that a watt-hour meter on a street car shows very little difference in current consumption whether the car runs on a track of heavy grade or on a level track. We have just heard that gasoline consumption is very much higher on highways having steep grades. If that is true, it seems to me to be the business of engineers who have to do with the gearing of trucks and automobiles to determine whether all of that difference is not due to the gears. When a truck moves on a good pavement having grades, there should be little difference in effect between it and the same pavement without grades. The gear situation is not essentially different from that of a street car, and the power consumption should obey the same laws.

R. P. LAY:—Many of the present highways are constructed under factors similar to those governing the construction of the old-style dirt roads. As a result, the

vehicle must be slowed down to negotiate the turns and bridges safely. Why should not new roads be laid out in straight lines as nearly as possible? When a curve is necessary, it should have a large radius, and bridges should be made wide enough that two vehicles can pass each other on them. The suggestion is made that the Government buy additional land on the inside of road curves, cut down trees and remove other obstructions to vision, so that car drivers can see whether the road beyond is clear and keep their cars at high speed.

MR. MOSKOVICS:—I wish to call attention to the fact those parts of the United States that have the best roads experienced the best automotive business in the past year. In California and the Eastern States, where practically each community has good intercommunicating roads, the business was less affected by the industrial depression than in any other part of the country. One of the first States to feel the automobile depression was Iowa, where roads are not developed as they are in these other sections. I know of nothing more effective that an automotive engineer can do to increase the eventual prosperity of the automotive industry than to cooperate with the road builders to secure more good roads throughout this country.

A railroad engineer does not stop at the science of building a locomotive; he interests himself in and has much to do with the rails and the roadbed. Why should not the automotive engineer act correspondingly in his field? He is in duty bound to his industry, to the institution he represents and to himself, to do everything he can to enlarge the sphere of use of automotive equipment and to make that use less costly and more convenient. No one would argue that anything would enhance more the convenience of motoring and the lowering of upkeep costs than really good roads.

Automotive engineers have done a considerable amount of talking on this subject; let them reduce this to a real practical basis. The Government of the United States, represented by Mr. Goldbeck, has asked for our cooperation. Let us go more than half way. I am going to make a formal motion to that effect, but I strongly urge that the subject be not dropped with the mere formality of passing a resolution, because I believe it is one of the most important things before the entire industry. It merits the best attention of the technical men of the industry. Therefore, Mr. Chairman, I move that it is the sense of the members assembled at this meeting that a committee should be appointed to cooperate with the proper highway officials at Washington by lending every aid of this Society, from a technical standpoint in the design of those products that are made by the manufacturers represented by the members, to assist those officials in their work. [The motion was carried unanimously.]

MR. GOLDBECK:—I am glad that this resolution of cooperation has been passed. I desire your cooperation with highway engineers in particular. I would like to see accomplished the getting together of those who have to do with the motor truck and those who have to do with the highway. Highway engineers are sometimes apt to design highways with the idea of getting mileage for a certain amount of money. That is wrong in principle. It neglects the fact that the highways have to carry a certain definite amount and maximum weight of traffic. In the past the motor-truck designer has not had in mind particularly the effect the truck has on the highways and the reduction of the ultimate cost of transportation, which is the thing I wish to see accomplished. I think that highway engineers have not understood automotive engineers, and that the reverse also is true. Let us solve our difficulties together.

EDUCATION FOR HIGHWAY TRANSPORT

BY CHARLES J. TILDEN

THE author discusses the kind of college education that should be offered to those who expect to become engaged in highway transportation by motor truck, with reference to organization, regulation and operation on a large scale. Stating that the main factors of such an education fall naturally into the three divisions of the highway, the vehicle and the business, these are considered with regard to what topics might be presented profitably to college students under these respective heads, the subjects and the factors that govern their desirability being commented upon in general terms.

The main principle which should be borne in mind in educating men for the motor-transport business and the main value of such an education lie in the intellectual development and ability to analyze critically, which give the student mastery over new situations as they arise, and ready adaptability to the needs of any given business situation. [Printed in the September, 1921, issue of THE JOURNAL]

THE DISCUSSION

ALFRED REEVES: — Professor Tilden, who has been granted a year's leave of absence from Yale, is director of the Highway and Highway Transport Education Committee, which is a volunteer committee supported by contributions and working with the Government installing highway-engineering courses in the colleges of the country to insure an even better grade of men to handle highway problems in the future than we have had in the past. It seems appropriate to follow Professor Tilden's paper by some facts relative to this road problem. Appropriations of some $624,000,000 are now available in this Country for road improvement; so it is important that we train men to expend this money in the most efficient way. The Townsend Bill now before Congress calls for $100,000,000, matching dollar for dollar the money appropriated by the States, and providing that the money shall be expended on interstate roads and not on unrelated sections of roads. The latter plan has wasted money and effort in the past.

Roy D. Chapin, who is the chairman of the National Automobile Chamber of Commerce Highways Committee, fought last year to prevent the passage of a bill at Washington that called for $100,000,000 for good roads. It passed the House and was defeated in the Senate. President Harding wanted to know why the automobile industry should object to such an appropriation for roads. When he found that our opposition was based on our feeling that the bill did not properly conserve the taxpayers' money, our position before Congress and our appeals were substantially advanced. President Harding in his last message called for more improved roads throughout the Country, and primarily for their maintenance after they are constructed. He declared that the motor car had become an indispensable instrument in our industrial, social and political life.

I understand that Mr. Kruttschnitt, of the Southern Pacific Railroad, assailed the motor truck on the ground

that it is cutting into the railroad business; that we had highways built for us with the taxpayers' money, whereas the railroads had to buy their own rights of way. The fact is that many of the railroads obtained their rights of way for practically nothing, with miles of additional land donated to them. Moreover, when a railroad builds a right of way, it has the exclusive use of it. When the public builds a highway, it is open to the world. The rivers and harbors are dredged by the Federal Government, but they are available for use by the ships of all the world for the benefit of all.

We find commodities moving over the four main channels of transportation, the highways, rivers or waterways, railroads and interurban lines. The position of the automotive industry, which I believe is sound, is that all transportation interests have a common ground and a common interest, that each has an individual function to perform, and that their manner of performing it will bring its own reward. In other words, insofar as the motor car or motor truck is a more meritorious medium of transportation than the railroad or the interurban trolley line, it will get its share of the business. The entire world is crying for more efficient methods of transport. The Society is to be congratulated on the big dominating part it is taking in helping to meet this urgent demand on the part of the public.

SAFETY FUEL-TANKS FOR AIRCRAFT

THE British Air Ministry has stated that the possibility of aircraft catching fire in the air has been almost entirely eliminated by care in design and inspection, but that such precaution is not sufficient to protect, in every case, an airplane from the results of a crash. One of the main objects to be attained is to insure that in a heavy landing or a crash the fuel-tanks on an aircraft, even though seriously damaged, will withstand the shock to which they may be subjected without either bursting or leaking. Accordingly, with the object of obtaining for use in service and commercial aircraft safety tanks that will fulfill these conditions and at the same time withstand the effects of enemy action by machine-gun and shell-fire a competition for safety fuel-tanks has been arranged to commence on Dec. 1, 1921.

Prizes to the extent of £2,000 will be awarded to the entrants of the tanks that are considered best. The first prize will be £1,400, the second £400 and the third £200. The competition will be held at a place to be decided upon later. Any competitor may enter several different types of tank, but two specimens of each type must be supplied for preliminary tests and four for the final tests. Entries, which should be addressed to the Secretary, Air Ministry, Kingsway, London, W.C.2., marked "Safety Fuel Tank Competition," will be received until Nov. 7, 1921. These should be made on a form that will be supplied on request. The control of the competition will be in the hands of a committee appointed by the Air Council. Its decision as to awards will be final and without appeal.

Tanks should be constructed so as to prevent as far as possible leakage or ignition of fuel when subjected to stresses similar to those to which the tank would be subjected in an aircraft crash and to machine-gun fire using incendiary armor-piercing or explosive ammunition. Equal importance is attached to these requirements.

A tank is to be capable of being fitted within a space of 2 x 2 x 2½ ft. and to have a capacity that must be within 5 per cent of 30 gal., but any shape of tank will be accepted for competition. All the necessary fittings to enable the tank to be mounted in a structure for testing purposes must be supplied by the competitor. The maximum weight, complete with fittings, which would be justified only by very exceptional qualities, should not exceed 1.75 lb. per gal. of capacity. Tanks exceeding this figure will not be disqualified, but great importance will be attached to low weight. In all cases the tank is to be complete with the necessary fittings to enable it to perform its functions of supplying fuel to a fixed point. In the case of tanks designed to incorporate leak detectors and similar instruments and devices, these will be fitted in such a manner as to show their efficiency under test, and will be included in the weight. In every case there must be at least one filler and also unions for supply and delivery connections, one of the latter at the top, the other at the bottom of the tank.

The relative importance of other characteristics of the tanks will be considered in the following order:

Light weight
Durability under service conditions in the absence of any accident[1]
Indifference to extremes of temperature
Adaptability of design to large capacities
Simplicity of construction
Adaptability of design to various shapes
Accessibility of fittings
Cost of production

All tanks will be subjected to preliminary trials. The three best types will be selected by the judges for a final trial. For the preliminary tests both tanks submitted will be subjected to a crashing test of the following nature:

> Each tank will be mounted in a wooden structure and located behind a concrete body formed to represent an engine. The tank will be released down a wire ropeway approximately 100 ft. high, arranged so that the structure will strike the ground at an angle of not less than 45 deg. from the horizontal and be free to turn over. This will insure as far as possible the conditions prevailing in a typical aircraft crash. The tank will contain 22 gal. of gasoline which will be supplied by the Air Ministry.

In the four tanks supplied for the final tests minor modifications of the original design may be made, provided the judges have previously decided that the modification is one of detail and not fundamental principle. The tanks will be required to undergo a crashing test similar to that in the preliminary stages and also a firing test in which they will be subjected to machine-gun fire with ammunition capable of penetrating the ordinary type of mild-steel fuel-tank and leaving small entry and large exit-holes when the tank is struck below the fuel level, and exploding and igniting the fuel either on contact or after penetration. A series of bursts of five rounds each will be fired at a range of 50 yd., the tank being examined after each burst. The angle of fire will be at the discretion of the judges.

At any time during the competition the judges may impose such other tests as they may desire to demonstrate the relative merits of competing tanks. There will be an interval of at least eight weeks between the preliminary and the final tests.

[1] In the case of scout aircraft the stress due to acceleration may amount to three or four times that due to gravity.

ACTIVITIES OF THE SECTIONS

Sections Calendar

BUFFALO
(Secretary—George H. Pettit, 1569 Jefferson Street, Buffalo)

CLEVELAND
(Secretary—E. W. Weaver, 5103 Euclid Avenue, Cleveland)

DAYTON
(Secretary—R. B. May, Dayton Engineering Laboratories, Dayton)
Oct. 4—All-Metal Design of Airplanes by I. M. Laddon

DETROIT
(Assistant Secretary Mrs. B. Brede, 1361 Book Building, Detroit)

INDIANA
(Secretary—B. F. Kelly, Weidely Motors Co., Indianapolis)
Oct. 7—Chassis Design by C. E. Jeffers

METROPOLITAN
(Secretary—F. E. McKone, 347 Madison Avenue, New York City)
Oct. 7—Aberdeen Proving Ground

MID-WEST
(Secretary—L. S. Sheldrick, 910 South Michigan Avenue, Chicago)
Oct. 7—Dinner at Chicago Automobile Club
Oct. 28—Technical Meeting

MINNEAPOLIS
(Secretary—C. T. Stevens, 13 South Ninth Street, Minneapolis)
Oct. 5—Manifold Design and Fuels

NEW ENGLAND
(Secretary—H. E. Morton, B. F. Sturtevant Co., Hyde Park, Boston)
Oct. 14—Address by C. H. Metz and Discussion of Massachusetts Headlight Law

PENNSYLVANIA
(Secretary—T. F. Cullen, Chilton, Co., Market and 49th Streets, Philadelphia)
Oct. 7—Aberdeen Proving Ground

WASHINGTON
(Treasurer and Acting Secretary—C. H. Young, 210 Riggs Building, Washington)
Oct. 7—Aberdeen Proving Ground

THE visit of the Society and of the Metropolitan, Pennsylvania and Washington Sections to Aberdeen Proving Ground on Oct. 7 in response to General Williams' invitation to be present to witness the tests and demonstrations to be given on that date, will constitute one of the most important meetings of the season. At the last Summer Meeting it seemed impracticable to stage an exhibit of ordnance materiel due to the expense involved. Because of the interest of our members, however, it was believed that a visit to the Proving Ground would be of greater benefit, since it is possible to conduct demonstrations there on a larger scale than elsewhere. The program given on another page indicates the scope of the tests. Arrangements have been made for special cars leaving New York on Thursday night, Oct. 6, and extra accommodations have also been provided from Washington and Philadelphia on the morning of Oct. 7. Those expecting to attend should notify the Commanding Officer, Aberdeen Proving Ground, Md., at the earliest possible moment, enclosing a check for $3 to cover the expense of the luncheon and the dinner that will be provided by an outside caterer.

SECTION MEETINGS

Most of the Sections have submitted complete or partial plans for their fall and winter programs.

The Dayton Section has reported the following schedule: Oct. 4, All-Metal Design of Airplanes by I. M. Laddon; Dec. 6, Lubrication by Dr. H. C. Dickinson, and March 7, Airplane Cooling Systems by Capt. Lorenzo L. Snow.

Detroit held its first fall meeting on Sept. 30, with an address by Dr. Dickinson. Tentative dates throughout the rest of the year have been fixed as Oct. 21, Nov. 18, Dec. 23, Jan. 24, March 24 and April 28. The contemplated subjects are Fuel Research, Aeronautics, Passenger-Car Bodies and Production Economies.

Indiana has called its first meeting for Oct. 7 at which C. E. Jeffers will give a paper on Chassis Design.

The Metropolitan Section reviewed the fuel papers of the Summer Meeting on Sept. 15. H. L. Horning led the discussion. On Oct. 7 this Section will join with the Society in its trip to the Aberdeen Proving Grounds. There will be a paper on Chassis Lubrication at the November meeting, including a discussion of approved methods and recent developments; a meeting on the Commercial Development of the Airplane in December; and, throughout the remainder of the year, papers on Factors Affecting the Design of Rear Axles for Trucks and Transmission Power Losses. In addition to these meetings, it is planned to hold a joint meeting with the New England Section at some southern New England point, which probably will take the form of a visit to a plant.

The Mid-West Section will hold an informal dinner-meeting on Friday, Oct. 7, at the Chicago Automobile Club, to which visitors are invited particularly. Plans for the winter program will be discussed at this meeting and a special effort made to increase the membership. It is expected that the first technical session will occur on Oct. 28. The Section proposes to hold a series of meetings throughout the fall and winter on the Fundamental Theories Underlying the Operation of Internal-Combustion Engines, including thermodynamic laws, principles of carburetion, advanced combustion phenomena and a study of the heat losses in an engine.

The members of the Minneapolis Section held their first fall gathering in the form of an inspection tour of the State Fair on Sept. 8. At meetings throughout the year there will be considered such subjects as Manifold Design, Fuels, Tractor Wheels and Traction, Steam Power for Farm Tractors, Road-Building Machinery and Engineering, Power Cultivators and Tools, Engine-to-Ground Power Absorption in Tractors and Tractor Publicity and Demonstrations.

The New England Section had an outdoor meeting in Worcester on Sept. 17. The October meeting will consist of an address by C. H. Metz, and a discussion of the Massachusetts Headlight Law. An ignition meeting will be held on Nov. 11, in Springfield; a meeting on aircraft development in December, probably at Worcester; a visit to the Stanley plant in Newton, together with a paper by E. H. Delling, chief engineer of the company, on Jan. 13; and an isolated lighting plant meeting at Boston or Worcester, with a paper by Mr. Wilkins of the H. C. Dodge Co. A spring meeting will be devoted to the discussion of the business aspects of the automotive industry. A joint meeting with the Metropolitan Section will conclude the Section program for the year.

The Pennsylvania Section spent the afternoon of Sept. 22 at Torresdale Golf Club, having dinner at Morrelton Inn. An evening session, the occasion of a short review of some of the important Summer Meeting papers, followed the dinner. President Beecroft was the guest of the evening. The Section will visit the Aberdeen Proving Grounds on Oct. 7. On No. 22 there will be a fuel and diesel-engine meeting. H. L. Horning and A. K. Brumbaugh will be the speakers. An aviation meeting is scheduled for Dec. 22, and it is probable that an inspection trip will be made to the Naval Aircraft Factory at the League Island Navy Yard. In Janury, 1922 it is intended to have a continuation of the discussion evoked by the Society's Annual Meeting papers. It is hoped to have a number of the authors of these papers in attendance. Current Business Conditions will receive attention at the meeting on Feb. 23; Batteries and Electrical Equipment on March 23; and Commercial Motor Transportation on April 27.

Current Standardization Work

ALTHOUGH the summer months have in past years generally been a period of inactivity for the Standards Committee members, the work of the last few months has resulted in great progress, several Division and Subdivision meetings having been held and reports submitted. A large amount of information has been obtained by the Standards Department for the use of Subcommittee members desiring to base preliminary recommendations on present engineering practice.

Division Meetings

At the meeting of the Parts and Fittings Division held on Sept. 12 in New York City several reports were accepted and will be submitted for action at the Standards Committee Meeting on Jan. 10, 1922. A meeting of the Engine Division was held on Sept. 20 in the rooms of the Old Colony Club, Hotel Cleveland, Cleveland. Several important subjects were discussed, including mufflers, engine numbers, engine testing-forms, fan belts and pulleys, engine torque, oil-pumps and water-pumps.

A meeting of the Transmission Division was held on Sept. 21 at Cleveland. A report on clutch facings, submitted by A. C. Bryan, was discussed. Other subjects acted upon at this meeting were gear-tooth strength formulas, transmission drive for speedometers, transmission tire-pump mountings and clutch-bearing oiling mechanisms.

The Passenger-Car Body Division members met on Sept. 23 at the Hotel Tuller in Detroit. Reports on body nomenclature, door-handle squares, door-fit clearances, nickel-plating, plate glass and top-irons were submitted for consideration.

A meeting of the Iron and Steel Division, held on Sept. 26 at Buffalo, indicated that a complete revision of the present iron and steel specifications and notes and instructions would be ready for Society action in January. On Sept. 27 the members of the Non-Ferrous Metals Division also met in Buffalo. Subdivision reports recommending revisions of and additions to the present non-ferrous metal alloy specifications were acted upon.

Aeronautical Safety Code

An organization meeting of the Aeronautic Safety Code Sectional Committee sponsored by the Society and the Bureau of Standards was held on Sept. 2 at New York City. H. M. Crane, chairman of the Aeronautic Division of the Society Standards Committee, was elected chairman, J. S. Ames of the National Advisory Committee for Aeronautics, was named vice-chairman and M. G. Lloyd of the Bureau of Standards, designated as secretary.

The chairman was empowered to appoint subcommittees, to facilitate the work of the Sectional Committee, one of which is to compile unbiased information giving the actual reasons for all airplane accidents in the future. It is expected that this information will be of great value in drawing up the safety code.

Body Top-Irons

A Subdivision report on top-irons has been submitted to the members of the Passenger-Car Body Division by O. H. Clark. It was based on a survey of present-day practice, representing a large variety of types and sizes, the great majority of which, however, specified a 7/16-in.—14 U. S. Standard thread. This thread was therefore specified for the top-irons recommended and should meet with general approval.

The top-iron types recommended cover all general requirements. The over-the-rail type top-iron is identical with a top-iron put out by a large manufacturer except that the length of the stud and the thread has been definitely specified. The through-the-rail type front top-iron also recommended can be used through the rail by body builders who do not wish to provide for the removal of the top-irons in case a permanent top is used. This type is superior to the separate through-the-rail type front and rear top-iron recommended in the report inasmuch as it is not necessary to counterbore such large holes through the rail for the top-iron sockets, which would naturally weaken the top rail.

Airplane Tachometer Drive

It is thought by some members that the S. A. E. Recommended Practice for Airplane Tachometer Drive should be revised by changing the diameter of the tachometer driving-shaft, page C76, S. A. E. Handbook, from 0.152 plus or minus 0.001 in. to 0.187 plus or minus 0.001 in. and changing the drill size and the hole diameter for the tachometer driving-shaft given on page C77 from Drill No. 20 (0.161 plus or minus 0.002 in.) to Drill No. 11 (0.191 plus or minus 0.002 in.). It has been stated that the dimensions of the tachometer shaft connection at the engine are not of suitable proportions to insure freedom from trouble, especially in the operation of the centrifugal type of tachometer that turns faster than indicated speed. The suggestions have been referred to the Powerplant Subdivision of the Aeronautic Division.

Carbureter Flanges

It was tentatively proposed at a recent meeting of the Engine Division to change the flange dimensions of the ½-in. carbureter size, page A8, S. A. E. Handbook, to conform with the flange dimensions for the ⅝-in. size and to change the dimensions for the ¾-in. size to conform with the dimensions for the ⅞-in. size, the actual inside diameters remaining the same. This revision is considered desirable because it would permit makers to purchase castings to better advantage, as four sizes of flange could be made from two sizes of casting and two sizes of gasket would be eliminated. The Division also plans to formulate a standard for motorcycle carbureter-flange dimensions.

Clutch Facings

The following report on clutch facings was submitted by A. C. Bryan at the Transmission Division meeting held Sept. 21:

SINGLE PLATE CLUTCHES

The majority of single-plate clutches are made in three sizes, 8, 10 and 12 in. In Table 1 are listed the single-plate clutch-facing sizes produced at present by leading companies.

TABLE 1—PRESENT CLUTCH-FACING PRACTICE

Size of Clutch, in.	8	10	12
Borg & Beck			
Inside Diameter, in.	5⅜	6¾	8¼
Outside Diameter, in.	7⅞	9⅞	11⅞
Detroit Gear & Machine			
Inside Diameter, in	5⅜	6⅞	...
Outside Diameter, in.	7⅞	9⅞	...
Hoosier			
Inside Diameter, in.	5½	6⅞	$8\frac{3}{16}$
Outside Diameter, in.	7⅞	9⅞	$11\frac{13}{16}$

In view of the fact that most single-plate clutches for passenger cars and trucks are similar in design and are housed by flywheels bored 8, 10 and 12 in., respectively, standard inside and outside diameters are proposed as shown in Table 2, as these sizes will fit present clutches without any change in the design of the clutch parts.

TABLE 2—PROPOSED CLUTCH-FACING PRACTICE

Size of Clutch, in.	8	10	12
Woven-Fabric Split Facings			
Inside Diameter, in.	5⅜	6¾	8¼
Outside Diameter, in	7⅞	9⅞	11⅞
Molded Ring Facings			
Inside Diameter, in.	5⅜	6¾	8¼
Outside Diameter, in.	$7\frac{31}{32}$	$9\frac{31}{32}$	$11\frac{31}{32}$
Thickness, in.	$\frac{5}{32}$	$\frac{5}{32}$	$\frac{5}{32}$

When woven-fabric facings are used in single-piate clutches, they work better with $\frac{1}{16}$-in. clearance all around, but molded facings must fit within $\frac{1}{32}$-in. clearance all around or they will cause a distinct noise when the clutch is released. This is due to the fact that facings in the majority of single-plate clutches are not fastened to the discs and will throw about when released, the hard molded facing causing the noise. Two sizes are therefore suggested, one for the molded facing and one for the woven-fabrc facing, as given in Table 2. The question of thickness will probably cause some discussion as both $\frac{1}{8}$ and $\frac{5}{32}$-in. thicknesses are used.

MULTIPLE-DISC CLUTCHES

A great number of multiple-disc clutches on the market are so varied in design as to make the standardizing of facing sizes for them somewhat more difficult.

In selecting sizes for facings in a multiple-disc clutch design, there are two factors to consider

(1) The inside diameter of the facing must be large enough to go over the driven hub. The hub size is largely governed by the spring construction used

(2) The outside diameter of the facing must be small enough to fit in the driving drum or spider

The S. A. E. Standard for Flywheel Housings, page A1, S. A. E. HANDBOOK, specifies the dimensions for attaching the driving drum or spider of a multiple-disc clutch to the flywheel. There is an advantage in having the mean radius of the facing as large as possible as the driving power of the clutch is directly proportional to this. I have ascertained from a number of layouts that a 8⅝-in. outside diameter facing is about the largest that can be used with an internal-gear or key-driving drum and allow the use of a socket-wrench to tighten the cap-screws holding the drum to the flywheel, using the dimensions specified in the S. A. E. Standard.

It is a direct advantage from the standpoint of cost to use as few facings and discs as possible in a multiple-disc clutch, but in so doing the spring pressure must be increased to take care of the torque and the width of the facing made such that the unit pressure on the facing is not excessive. Another advantage is the fact that the travel necessary to release the clutch is more or less proportional to the number of discs, so that the high spring-pressure necessary can be provided easily by a linkage without excessive travel of the pedal.

The Raybestos Co., after much experimenting, recommends a unit pressure of 20 lb. per sq. in. on molded facing and a coefficient of friction of 0.16, which it has found will give good service with a large factor of safety. S. O. White has recommended a facing size of 8⅝-in. outside diameter with a 1¼-in. face and an inside diameter of 6⅛ in. The area of this size of facing is 29 sq. in. and with it a five-plate clutch, capable of transmitting the torque of the heaviest engines used in passenger-car or truck work, can be designed by use of the following formula:

$$T = (n \times S \times r \times f) / 12 \qquad (1)$$

where

f = the coefficient of friction
n = the number of facings
r = the mean radius = 3.69 in.
S = the spring pressure
T = the torque in pound-feet

Twenty pounds per square inch unit pressure with 29 sq. in. of surface requires a 580-lb. spring.

Substituting in formula (1) we have

$$T = (10 \times 580 \times 3.69 \times 0.16) / 12 = 285 \text{ lb.-ft.} \qquad (2)$$

This provides for a much more powerful engine than is ordinarily used in the heaviest trucks or passenger cars. In actual practice, in all probability, the figures given will not be realized due to design and inaccuracies in machining and assembling; but it seems that this five-plate clutch would actually take care of the engines ordinarily used in the heaviest passenger cars or trucks so far as facings are concerned.

Another facing size that should be adopted is 8⅝-in. outside diameter and 6⅝-in. inside diameter with a 1-in. face. This would have a mean radius of 3.812 in.

$$T = (8 \times 350 \times 3.81 \times 0.16) / 12 = 144 \text{ lb.-ft.} \qquad (3)$$

From the above it is evident that a four-plate clutch with a 350-lb. spring, which is commonly used, will handle an engine ordinarily used in the lighter passenger cars and speed trucks.

Another point is that by using this size of facing the driven hub can be carried over the flywheel bolts, saving considerable length in the clutch, the transmission main drive-gear and the transmission housing, which is an item in cost. Care must be taken in clutch designs using large facings not to have too much revolving weight in the driven member as this might tend to cause trouble in gear-shifting.

It is desirable at times to use smaller-diameter facings than those mentioned above, the size depending on the spring construction and the length available for the number of facings needed. There are a number of satisfactory disc clutches on the market having facings with an inside diameter of from 5¾ to 6¼ in. and an outside diameter of from 7¾ to 8⅛ in. Within this range the 6-in. inside diameter and 8-in. outside diameter seem to be the most popular and work out very satisfactorily. It may, however, be advisable to have more than one size within this range. This point will need serious consideration.

Summing up, I recommend that the sizes of clutch facing shown in Table 3 be adopted as S. A. E. Standard.

TABLE 3—PROPOSED S. A. E. STANDARD CLUTCH-FACING SIZES

Size of Clutch, in.	8	10	12
Single-Plate			
Inside Diameter, in.	5⅜	6¾	8¼
Outside Diameter (Fabric), in.	7⅞	9⅞	11⅞
Outside Diameter (Molded), in.	7 11/32	9 11/32	11 11/32
Multiple-Disc			
Inside Diameter, in.	6⅛	6⅝	6
Outside Diameter, in.	8⅝	8⅝	8
Thickness	5/32	5/32	5/32

CONNECTING-RODS

A report, consisting of curves, has been submitted by G. M. Ozias, chairman of the Stationary Engine Subdivision on Connecting-Rods, covering the following connecting-rod relationships:

Connecting-rod lengths against strokes, in inches
Crankpin diameters against bores, in inches
Piston-pin diameters against bores, in inches
Crankpin diameters against crankpin lengths, in inches
Projected areas of the piston-end connecting-rod bearing, in square inches, against bores, in inches
Projected areas of the crank-end connecting-rod bearing, in square inches, against bores, in inches

The curves were plotted from data obtained from 16 different makes of single-cylinder stationary engine and will be discussed and acted upon at the next meeting of the Stationary Engine Division.

GREASE-CUPS

It has been argued that the Society should standardize a definite series of grease-cup sizes for use on automotive vehicles. Information is being obtained as to present practice.

DOOR-FIT CLEARANCES

As standard door-fit clearances would be of great assistance to body engineers, the Passenger-Car Body Division has tentatively recommended the following clearances:

Location	Clearance, in.
Hinge Side	⅛
Lock Side	3/16
Bottom	7/32
Top	⅛
Jamb	3/16
Bead	3/32

These clearances are for all types of body and are measured from wood-to-wood or metal-to-metal before painting. The top clearance does not apply to open bodies.

Engine Torques

It has been stated by a member of the Electrical Equipment Division that in the application of starting and lighting equipment an S. A. E. Standard recommending a given starting torque and a given cranking speed for an engine of a given piston displacement would be helpful to both the car builders and the makers of starting and lighting equipment. The torque and speed would, of course, have to be different for engines with different numbers of cylinders as well as for engines of different types.

Lamp Glasses

It has been suggested that the present S. A. E. Standard for lamp glasses, page B6, S. A. E. Handbook, be extended to specify the dimensions given in Fig. 1 of the locking lugs of the head-lamp glass rim, to prevent the glass from turning in the lamp.

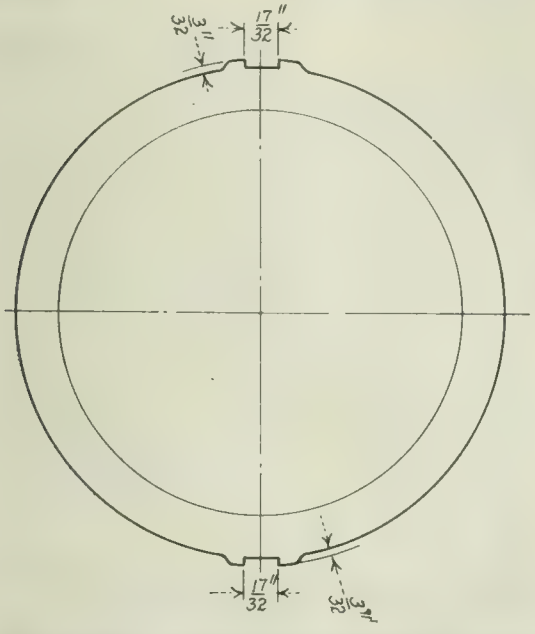


Fig. 1—Proposed Arrangement of Head-Lamp Glass Rim To Prevent the Glass from Turning in the Rim

Tail-Lamps

The standardization of tail-lamp overall dimensions and mounting screws has been suggested in view of the great variety of mountings used at the present time that might easily be reduced to one standard design, acceptable to both lamp and automobile manufacturers. The dimensions tentatively recommended, given in Fig. 2, are in accord with present practice. The advantages claimed to result from the use of this construction are

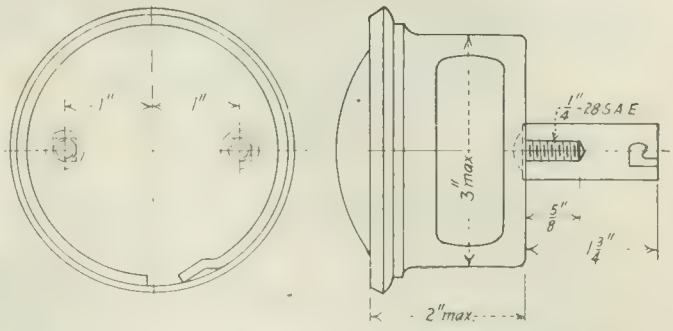


Fig. 2—Tentative Recommendation for a Standardization of Tail-Lamp Overall Dimensions and Mounting Screws

(1) The tail-lamps can be mounted on either the right or the left side of the license-plate, thus eliminating the necessity of making right and left lamps, which is the practice at present
(2) The socket coming out at the center of the back of the lamp makes the wiring very simple
(3) The holes in the bracket on the automobile can be drilled on the vertical line, thus allowing the lamp to be mounted either above or below the license bracket
(4) As the bulb is in the exact center of the lens, even illumination of the lamp glass, regardless of the length of the bulb socket or the diameter of the tail-lamp shell, is obtainable

Flywheel Housings

The present S. A. E. Standard for Flywheel Housings, pages A1 and A2, S. A. E. Handbook, specifies that the minimum diameter of the clearance space for crankshaft flywheel-bolt heads shall be 6⅛ in. and the minimum depth ⅝ in. As these are the actual dimensions and should, in the opinion of a member of the Engine Division, be increased to allow a clearance of ⅛ in. on the diameter and a clearance of 1/16 in. over the nuts, the standard will be reopened at an early date.

Shaft and Housing Fits and Tolerances for Ball Bearings

The Ball and Roller Bearing Division has under consideration a revision of the Information on shaft and housing fits and tolerances for ball bearings published on page C33 of the S. A. E. Handbook. This general information, which was accepted for publication in March, 1921, has been criticized to the effect that the housing fits are too close for commercial machine-work. This question will be thoroughly discussed at the next meeting of the Division.

RADIO-CONTROLLED AUTOMOBILE DEVELOPED BY THE AIR SERVICE

THE most interesting part of the radio-controlled automobile developed by the engineering division of the Air Service at Dayton, Ohio, is the selector that is the heart of the entire control system. Various combinations of dots and dashes are sent out by a specially constructed transmitter, each combination calling for the accomplishment of a certain operation of the control apparatus. It is the function of this selector to decode these various combinations of dots and dashes and to close the circuits to the desired controls. So delicately is this selector constructed and so rapidly will it operate, that it is possible to put into operation any one of 12 distinct controls in a period of less than 1 sec. The car has been controlled equally well from an airplane and a ground transmitting station. It is about 8 ft. long and runs on three pneumatic-tired wheels at a speed of from 4 to 10 m. p. h. It is said that it can be steered easily by radio along a narrow roadway.

The possibility of radio control and its application to wartime problems are almost without number. Radio control can be supplied to any mechanical apparatus that moves, whether it be in the air, on the ground, on the surface of the water or beneath the water.—Air Service News Letter.

Applicants *for* Membership

The applications for membership received between Aug. 21 and Sept. 16, 1921, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

BARTLETT, PERCY H., chief tester, Sinclair Refining Co., *Oak Park, Ill.*

BEEGLE, CLIFFORD H., salesman, Union Drawn Steel Co., *Detroit.*

BUSHNELL, SHERMAN W., automotive engineer, Sherman W. Bushnell, *Seattle, Wash.*

CASSILLY, MERLE E., tractor repairman, Rock Island Arsenal, *Rock Island, Ill.*

CHENOWETH, OPIE, field man, Peoples Loan & Trust Co., *Winchester, Ind.*

CLERK, DUGALD, SIR, civil engineer, National Gas Engine Co., Ltd., *Ashton-under-Lyne, England.*

CONNOR, P. J., mechanic tool salesman, E. L. Easley Machinery Co., 555 West Washington Boulevard, *Chicago.*

EVANS, CLARK, student, University of Michigan, *Ann Arbor, Mich.*

FLAGE, JOHN E., superintendent of manufacturing and assistant chief engineer, Ray Battery Co., *Ypsilanti, Mich.*

GRABOW, FRED C., designer, Shaw-Enochs Tractor Co., *Minneapolis.*

GRANDSTAFF, BEN F., manager repair parts department, Munger Automobile Co., *Dallas, Tex.*

HURD, RALPH H., engineer, Libby & Huls, *Chicago.*

KERSHAW, LEONARD F., draftsman, Fox Motor Car Co., 7th and Grange streets, *Philadelphia.*

KOERBER, ARTHUR W., draftsman, O. E. Szekely Engineering Co., *Moline, Ill.*

KRAUSE, EMIL F. W., expert and sales organizer, Utility Battery Co., *Chicago.*

KUBACKA, JOSEPH E., body engineer, Victor Pagé Motors Corporation, *New York City.*

KULICKE, F. W., sales engineer, Atwater Kent Mfg. Co., *Philadelphia.*

LA HATTE, MILNER T., division manager and associate engineer, Selden Truck Corporation, *Rochester, N. Y.*

LINCOLN, JOSEPH B., mechanical engineer, Naval Engineering Experiment Station, *Annapolis, Md.*

MERRITT, RALPH V., general foreman, Brewster & Co., Inc., *Long Island City, N. Y.*

MOHORI, TERUO, Japanese Government student in agriculture and commerce, 13816 Argus Avenue, *Cleveland.*

NEELANS, HAROLD G., student, University of Michigan, *Ann Arbor Mich.*

PARR, C. H., engineer, Hart-Parr Co., *Charles City, Iowa.*

POMY, HERMAN J., factory representative, Self Seating Valve Co., *Chicago.*

SCHAGELIN, EDWARD G., service superintendent, Nash Sales Corporation, 440 Mercer Street, *Jersey City, N. J.*

SENIOR, THOMAS K., assistant chief engineer, Cleveland Automobile Co., *Cleveland.*

SHEAFF, HOWARD, draftsman, Wittemann-Lewis Aircraft Co., *Hasbrouck Heights, N. J.*

SHEEHAN, DANIEL J., student, University of Michigan, *Ann Arbor, Mich.*

UNDERWOOD, ARTHUR J., student, University of Michigan, *Ann Arbor, Mich.*

WHEELER, RICHARD F., buyer, Stevens-Duryea, Inc., *Springfield, Mass.*

WING, WILFORD W., service engineer, Frigidaire Corporation, *Dayton, Ohio*

Applicants *Qualified*

The following applicants have qualified for admission to the Society between Aug. 10 and Sept. 9, 1921. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

APPERSON, EDGAR L. (M) president, Apperson Bros. Automobile Co., *Kokomo, Ind.*

BIRMINGHAM, C. J. (A) service manager, Locomobile Co., 16 West 61st Street, *New York City.*

BROCKETT, ASHLEY H. (M) instructor in automotive engineering, Carnegie Institute of Technology, *Pittsburgh,* (mail) 1835 Bluff Street.

DOYLE, JOSEPH A. (A) sales, service, Stromberg Motor Devices Co., 68 East 25th Street, *Chicago.*

GEE, HAROLD W. (J) assistant superintendent, gas works, Georgia Railway & Power Co., Atlanta, Ga., (mail) 529 North Church Street, *Decatur, Ga.*

GOSSLING, W. E. (M) storage battery engineer, Prest-O-Lite Co., Inc., 30 East 42nd Street, *New York City.*

GIBSON, ALLEN W. (A) special representative, Prest-O-Lite Co., Inc., New York City (mail) 132 23rd Street, *Elmhurst, N. Y.*

HARMON, C. O. (A) sales, Cleveland Experimental Laboratories Co., *Cleveland,* (mail) 1747 Bryn Mawr Avenue, East.

HOOVEN, ALBERT M. (A) secretary and treasurer, Meteor Motors Corporation, Philadelphia, (mail) 25 North Wycombe Avenue, *Lansdowne, Pa.*

INSLEY, ROBERT (J) aeronautical mechanical engineer, engineering division, Air Service, McCook Field, *Dayton, Ohio,* (mail) Powerplant Laboratory.

KELLY, RAYMOND J. KING (A) automobile race driver, designer, builder and aviator, J. Alex. Sloan, *Chicago,* (mail) 5958 Washington Boulevard.

LEE, ROY E. (M) chief draftsman, Russell Motor Axle Co., *Detroit,* (mail) 1998 Leslie Avenue.

LOVE, HORACE (A) H. H. Franklin Mfg. Co., *Syracuse, N. Y.*

MARTIN, P. B. (A) manager, service stores, Westcott Motor Car Co., *Springfield, Ohio,* (mail) 126 East Cassilly Street.

MURRAY, ROBERT ROY (A) mechanical superintendent, Provincial Highways Board, *Halifax, N. S., Canada,* (mail) 4 Carleton Street.

ORTEIG, JULES P. (A) president, Orteig Motor Co., *New York City,* (mail) 317 West 99th Street.

PATRICK, FRANK E. (A) sales representative, Acme Storage Battery Corporation, Poughkeepsie, N. Y., (mail) 144 Lakeland Avenue, *Cleveland.*

PIERCE, J. OTIS (A) sales manager, Brown-Lipe Gear Co., *Syracuse, N. Y.* (mail) 1117 West Fayette Street.

PROSPERI, A. G. (A) sales engineer, Oakland Motor Car Co., *Atlanta, Ga.,* (mail) Wyndham Courts.

SHRUM, A. T. (J) chief draftsman, Walker Vehicle Co., State and 87th Streets, *Chicago.*

STROHM, GROVER E. (A) sales engineer, Prest-O-Lite Co., Inc., New York City, (mail) 541 East Larned Street, *Detroit.*

TIPTON, WILLIAM D. (J) 1618 St. Paul Street, *Baltimore.*

VALTIER, FRANK (M) industrial engineer, Milburn Wagon Co., Monroe Street, *Toledo.*

WEINBERG, SAMUEL (E S) automobile engineering student, draftsman, 135 Stockton Street, *Brooklyn, N. Y.*

WILLETT, E. F. (A) manufacturers agent, National Gauge & Equipment Co., La Crosse, Wis., (mail) 4835 Woodward Avenue, *Detroit.*

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. IX November, 1921 No. 5

Winter Meetings

PLANS for the winter meetings of the Society are now well advanced and it is possible to announce many details of the programs at this early date. The Annual Meeting will be held at New York City, Jan. 10-13; the Chicago Meeting will be convened, Feb. 1, during Show Week, and the Annual Tractor Meeting is scheduled for Minneapolis, Feb. 8, during the week of the National Tractor Show. The Meetings Committee also has plans under consideration for other national meetings but dates have not been decided upon devnitely for them.

THE ANNUAL MEETING

The technical sessions during the Annual Meeting will all be held in the Engineering Societies Building, 29 West 39th Street, New York City, where the headquarters of the Society are located.

Standards Committee Report

The Standards Committee will hold its meetings Tuesday morning and afternoon, Jan. 10. A large number of the Divisions of the Standards Committee have been very active during the summer and fall preparing reports on many subjects for submission at these meetings. One of the most important reports will be that of the Iron and Steel Division. The work of completely revising, and extending, the well known S.A.E. Steel Specifications has been completed. The report of the Division is the result of months of study and many sessions of its members.

Aeronautic Session

An Aeronautic Engineering Session will be held Tuesday evening, when a paper on Air-Cooled Engines will be presented by Charles Lawrance, a member of the Society who has specialized on this type of powerplant for airplane use. Other papers are contemplated for this meeting but have not yet been selected.

Business and Research

The Business Meeting, to be held Wednesday morning, will differ somewhat from those of previous years. It is intended to have the formal reports of the officers preprinted in full and circulated so that only very brief oral presentation of them will be necessary in the meeting itself. The time saved in this way will be devoted to careful consideration of the organization and future plans of the Society's new Research Department. Dr. H. C. Dickinson, the manager of the department, and H. M. Crane, chairman of the Research Committee, will lead the discussion.

Bodies, Lubrication and Trucks

Three simultaneous sessions will be on Wednesday afternoon, on Body Engineering, Lubrication, and Commercial Vehicles. The Body Engineering Session will be opened with a paper on Harmony in Car Upholstery by R. F. Quaintance, who has been identified with the manufacture of upholstering materials for a number of years. This will be followed by a paper on Body Seating-Dimensions, by George E. Goddard. L. V. Pulsifer, a chemist specializing in the paint and varnish field, will read a paper on the Manufacture and Proper Application of Automobile Paints and Varnishes. The so-called California Top, which has become very popular throughout the entire Country in recent months, will be discussed by Paul W. Steinbeck, a body engineer of long experience.

The Lubrication Session will include three papers by men who have made intensive study of problems in this field; Neil MacCoull of the Texas Co.; W. H. Herschel of the Bureau of Standards and Robert E. Wilson of the Massachusetts Institute of Technology.

Only one paper can be definitely announced now for the Commercial Vehicle Session. This will be presented by M. C. Horine, the subject being the Economics of Truck Transportation. Other features of this session will be announced in due course.

Ricardo to Present Paper

A matter of unusual interest is the announcement that Harry Ricardo, of Great Britain, has accepted the invitation of the Society to visit this Country and address the members at the time of the Annual Meeting. The conspicuous research studies of Mr. Ricardo in the field of automotive engineering are widely known. The quantitative results of his fuel investigations and his work on combustion-chamber forms, turbulence, stratification and supercharging have been published extensively. His study of mechanical losses in internal-combustion engines led to the development by him of novel and interesting piston designs.

Mr. Ricardo's paper at the Annual Meeting will be based upon his research work and contains much valuable automotive engineering data. The entire morning session on Thursday will be devoted to the presentation and discussion of the Ricardo paper. This arrangement has

been made because it is expected that the members will want to discuss the paper very thoroughly after its presentation at this session.

Fuel and Materials Sessions

There will be two simultaneous sessions on Thursday afternoon, one on Fuel and Engines and the other on Automotive Materials. In the former Thomas Midgley, Jr., and W. K. Gilkie will give a joint paper describing a study they have made of combustion by the spectroscope. This will be followed with a paper by O. C. Berry on exhaust temperatures and evaporation of engine fuels. A method of measuring detonation or fuel knock will be the subject of a second joint paper submitted by T. A. Boyd and Thomas Midgley, Jr. It is expected that the Bureau of Standards also will cooperate in this meeting.

The Automotive Materials Session will assume the form of a symposium on the recent development of the metals entering into the construction of automotive vehicles, and will include several papers. Aluminum and its alloys will be treated by Zay Jeffries, malleable iron by Enrique Touceda and rolled forgings by G. R. Norton. It is planned to have additional papers on drop-forging practice and alloy steels. It is the purpose of this session to acquaint the members with the advances made in these materials that assure the accomplishment of lighter designs for vehicles without reducing the strength of the various parts appreciably.

Passenger Cars

On Friday morning there will be a Passenger-Car Session, the major part of which will be devoted to the discussion of brakes. J. Edward Schipper will present a paper that brings together many dimensional and descriptive data on brakes, and S. Von Ammon will describe the comprehensive tests of brake-linings that have been conducted at the Bureau of Standards. It is stated that the tests have established coefficients of friction applicable to brake design which can be accepted as accurate in view of the multiplicity of tests from which they were derived.

Carnival and Dinner

The Carnival of 1922 will be held at the Hotel Pennsylvania, Wednesday evening, Jan. 12. It is the one big family social event of Show Week and by past performance has become an established feature of the Annual Meeting. This year the responsibility for the success of the Carnival rests with B. G. Koether, and that fact alone will convince those acquainted with him that a good time will be had by all. The Annual Dinner will take place in the spacious ballroom of the Hotel Astor as in years past. The Dinner is the largest gathering of representative automotive men at the banquet table in the year. Men representing the production, distribution, engineering and financial groups will be seated there. C. F. Kettering will again serve in the capacity of toastmaster as a result of popular demand.

THE CHICAGO MEETING

The Society will hold a dinner on Wednesday of Automobile Show Week in Chicago. This falls on Feb. 1. The Hotel Drake has been selected as the place for this event. Morning and afternoon meetings also will be held on this same day and both of these will be concerned principally with problems of service, operation and maintenance. Appreciation of the need for concerted study of the service man's troubles is increasing constantly and it is the object of these meetings to encourage the further investigation of every means of reducing operating expense.

MINNEAPOLIS TRACTOR MEETING

The Tractor Show will be held this winter at Minneapolis and the Society has made arrangements for its 1922 Tractor and Farm Power Meeting in that city on Feb. 8, during the Show, inasmuch as a large percentage of the members engaged in this branch of the industry will be there at the time. A Farm Power Dinner will be given and at least two technical sessions held. It is anticipated that the Minneapolis Section members will take a very active part in the conduct of this meeting, since their interest lies largely in the farm power field.

BALL BEARINGS

THE steel balls manufactured by Rudge-Whitworth, Ltd., in all sizes up to ½-in. diameter are cold-headed from a special chrome alloy steel, and above ½-in. diameter are hot-forged from a similar material. Each ball rod is tested before and after use, the balls being etched, crushed and compressed after the grinding operation, so as to reveal the microstructure and any minute scratches incurred during polishing. Other samples are subjected to a running test, in which each ball is put under 10 times the guaranteed load. In a crushing test three balls are compressed in a line until the middle one breaks, thus indicating the toughness. The spherity is tested by subjecting the balls to various loads and measuring the flats microscopically. These balls are made in all sizes ranging from ⅛ to 3 in. in diameter.

The Hoffmann steel balls are guaranteed to be within 0.0001 in. of standard, both as regards size and spherity. The races are ground, and afterward highly finished, as it is obvious that the surface on which the balls are to run must be as highly finished and as accurate as the balls themselves; otherwise the skill and care involved in the turning out of a high-grade ball is practically useless. Eventually the races are inspected, and gaged four times on all dimensions, this of course being exclusive of the gaging carried out by the operators during manufacture. These gaging operations are performed during assembly, after the whole of the machining processes have been completed. All these measurements, which naturally involve a high degree of accuracy, are based on standard end-measuring rods that are tested frequently at the National Physical Laboratory.

Hoffmann journal bearings are tested for outside diameter, bore of the inner race, width, face and track diameter of both races, and the radii of the corners of the outer and inner races. After assembly the bearings are checked for concentricity of face and outside diameter with the bore of the inner race. Simple thrust bearings are tested for outside and inside diameters, thickness, curvature and depth of ball-track, concentricity of ball-track with inside and outside diameters, and, further, each ring is carefully examined for warping or buckling.

Whatever friction exists in ball bearings remains practically constant even after years of hard wear. Provided the bearing is well made and correctly mounted, its efficiency will not deteriorate.

Though ball bearings need little care when once properly mounted, lubrication is very important, and the makers, as a rule, recommend a suitable oil or grease. It is naturally essential that the lubricant used should be entirely free from any impurities such as dust or other gritty substances; further, it should also be neutral, that is, free from alkali or acid.—*Engineering Production* (London).

Fuel Research Developments

By C. F. Kettering[1]

Annual Meeting Paper *Illustrated with* Charts and Diagrams

TWO distinct problems are involved in fuel research work, multi-cylinder distribution and the chemical constitution of the fuel mixture after it enters an engine cylinder. In discussing elementary combustion, the author refers to the components of the energy of combustion as gravitational, kinetic and barometric, and elaborates his theme with the aid of diagrams and charts showing normal and abnormal combustion.

After emphasizing the necessity of theorizing at some length, anti-knock substances are discussed, inclusive of substances apparently dissimilar that have the same chemical constituents. The ignition point and fuel utilization are treated, followed by comments upon fuel studies that have been made, with accompanying indicator-cards. The future objectives of fuel research are outlined as being along lines of physical and of thermochemistry, the simple laws of elementary physics, and cooperation with the producers and refiners of the fuel.

IN again taking up the subject of fuels, I think that from every standpoint we have made wonderful progress in the past year. The laboratories that have been working on this problem have found out some things and so has the public; the refiners have joined in and I believe that we really have approached a position now where we know approximately what we are talking about.

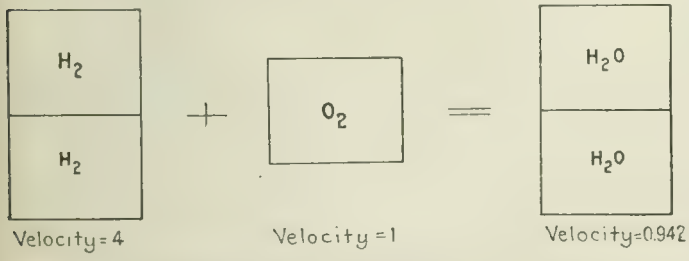


Fig. 1 -Composition of Hydrogen and Oxygen

Even if we have not solved the problem, we have at least agreed that the solution we are seeking lies in a certain direction. I believe that we do not realize what a heterogeneous mental attitude we have had.

There is a deadline in the automotive industry. We might just as well recognize it as being our fuel situation. If we can get cooperation between the oil producers and the automotive engineers, so that we may know where that deadline is and so that no one steps over it unintentionally without knowing that it is there, I think we can do some really constructive engineering work. But we must take that deadline into account and know not only the quality of our fuel today and what its local distribution is, but also what its end-point is going to be in 3 to 5 years from now.

Two distinct problems are involved in this fuel work. First comes the question of multi-cylinder distribution. I believe that none of us can appreciate just how important a factor distribution is until we have taken a single-cylinder engine, in which the factor of distribution has been eliminated, and experimented with it. When

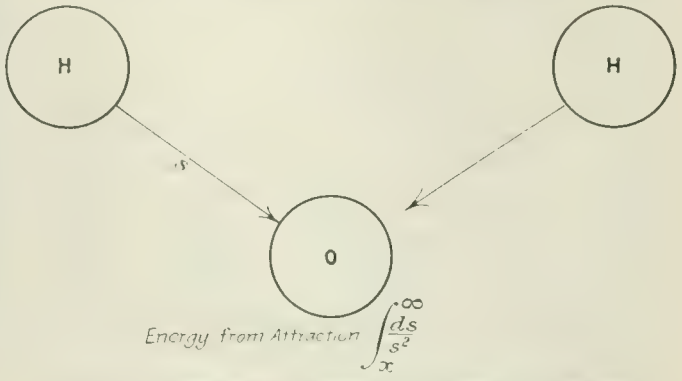


Fig. 2—Gravitational Energy of Hydrogen and Oxygen

we get the variations in mixture, the power, the temperatures of the cylinder walls and the exhaust, and the temperatures of the water-jackets for lean and for rich mixtures, we will begin to understand what percentage of this problem belongs to distribution and what percentage to the chemical side of it after the mixture gets into the cylinder. We can run a single-cylinder engine economically when the air going into the carbureter is 10 deg. below zero fahr. We can run it at 15 lb. per sq. in. higher compression with air 10 deg. below zero than we can with air at room temperature; and yet, theoretically, we ought to have hot air on that kerosene carbureter. But we discover, as we adjust the carbureter for leanness and richness, that adjustment makes considerable difference from the standpoint of economy, as well as from the standpoint of power. After we get the proper adjustment, we presuppose that, if the carbureter measures off a certain definite and correct amount of fuel, the same correct proportion will land satisfactorily in all of the cylinders of a multi-cylinder engine. So, we have confused the problem of distribution with that of chemical constitution. These two things are entirely different. Usually, what helps the one, makes the other worse, but when they get hitched together, they make a fine pair.

Let us go back and define a few things; our nomenclature has got us into a wrong way of thinking. We talk about heat without having any physical conception of it. According to the best information available today, heat is nothing but molecular velocity. Whether a thing

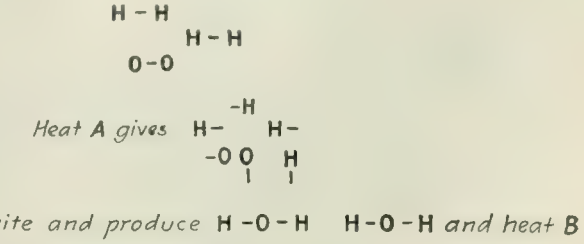


Fig. 3—Heat of Combustion of Hydrogen and Oxygen

[1]M.S.A.E.—General Motors Research Corporation, Dayton, Ohio.

is hot or cold depends only on the magnitude of its molecular velocity. In considering heat we are dealing with motion.

Elementary Combustion

It will be interesting and of assistance in helping us to think about heat as a function of kinetic energy and a function of velocity and motion, to consider a most

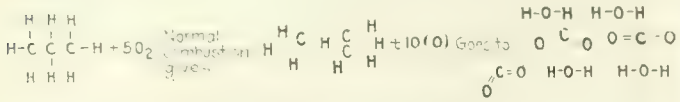


Fig. 1 Normal Combustion of Propane

elementary case of combustion. Fig. 1 is based primarily upon the combustion of hydrogen and oxygen. Suppose two containers, one of hydrogen and one of oxygen, are set alongside of each other. They are at the same temperature. According to the kinetic theory of gases, the kinetic energy of the gas inside of a container for a definite temperature and pressure is the same for all gases, and there are the same number of molecules in the container regardless of what the gas is. Let us suppose that two containers of hydrogen gas, which has an atomic weight of 1, or a molecular weight of 2, are alongside one container of oxygen, which has an atomic weight of 16 or a molecular weight of 32. If they have the same amount of molecular energy and an equal number of particles of each are in the containers, the hydrogen gas must move just four times as fast as the oxygen. When combustion occurs, or when the oxygen and hydrogen go together, the hydrogen is slowed down because the heavy oxygen molecule cannot run along with it at its former speed; so, some energy is given up by retarding the velocity of the hydrogen gas. But when oxygen and hydrogen burn and cool back to the temperature at which combustion began, the amount of gas has been reduced. Therefore, some energy has come by a change of volume. But the major part of that energy has come from another source, that is from the gravita-

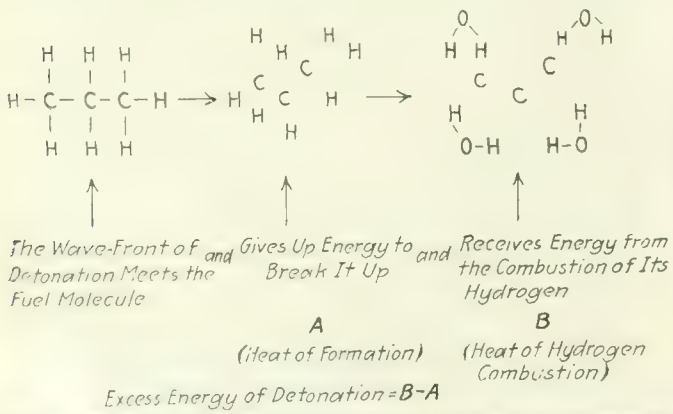

The Wave-Front of Detonation Meets the Fuel Molecule
and
Gives Up Energy to Break It Up
and
Receives Energy from the Combustion of Its Hydrogen
A
(Heat of Formation)
B
(Heat of Hydrogen Combustion)
Excess Energy of Detonation = B-A

Fig. 2—Diagram Showing the Abnormal Combustion of Propane

tional energy of the hydrogen molecule falling toward the oxygen molecule.

The components of the energy of combustion are gravitational, kinetic and barometric. It is very interesting to take some of the more elementary combustions and study them along this line. The gravitational energy is the energy which has been liberated by bringing closer together the centers of gravity of the oxygen and hydrogen particles. The kinetic energy is the change in the velocity of motion of the particles. The hydrogen was going fast; the oxygen was going slow. When they came together, the total mass slowed down considerably

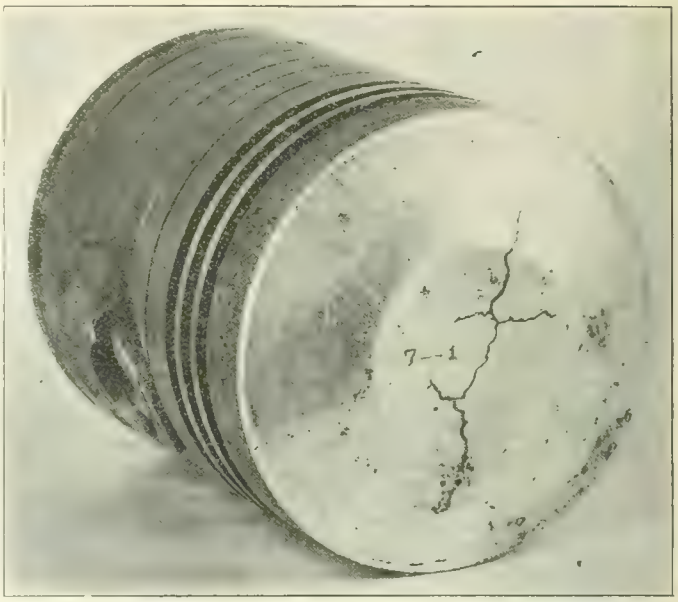


Fig. 6—A Liberty Engine Piston, the Top of Which Was Cracked as the Result of Being Subjected to Excessive Pressure

and that gave kinetic energy. The barometric energy is represented by the decrease in volume.

Let us consider an oxygen and a hydrogen particle as shown in Fig. 2 and that they are going to come into combination. A line integral of the distance between them, represented by s, is shown. It approaches from infinity, which is not necessarily very far, because these

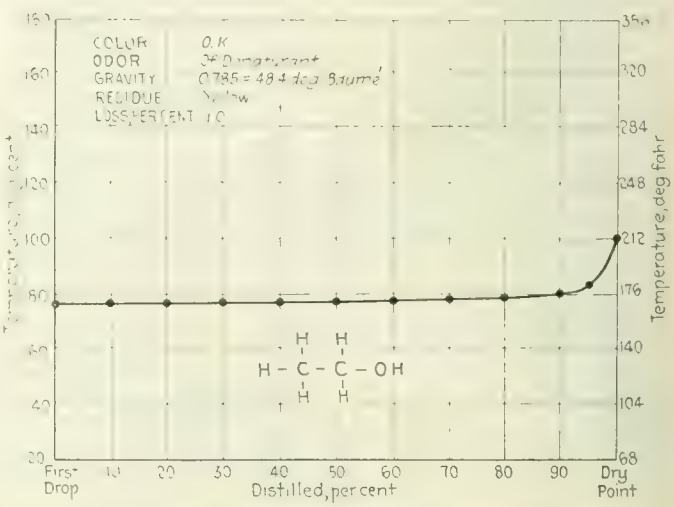
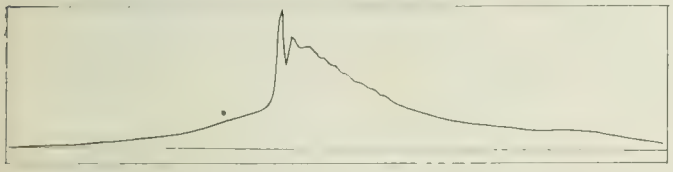


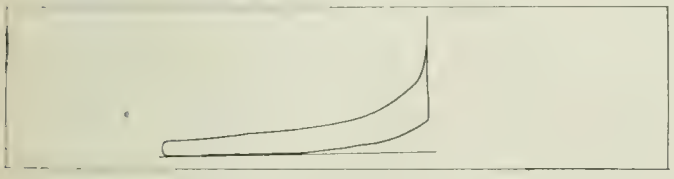
Fig. 7—Fuel Study of Commercial Denatured Alcohol

particles are very, very small and just a little bit is infinitely great. The amount of energy is the same in principle as that of the falling of a stone to the ground and is worked out in the same way. The mathematical formula for energy given in Fig. 2 is just a general expression of gravitational energy. The only reason we cannot figure it exactly is that we do not know the distance between the oxygen particle and the hydrogen particle. When we once get that, we will be able to know specifically what these things are. But we calculate the amount of energy liberated by this new set of static conditions exactly as we would the amount of energy developed from the falling of a stone. If those particles cause a great agitation as they come together, that represents heat; it is simply an oscillatory vibration of the particles as they bump back and forth.

Now let us consider the kinetic energy. As we expand a gas, we cool it. When we cool a gas, we simply take the velocity out of the particles. That is the only difference between a hot and a cold gas. If we consider heat as a type of velocity and that an engine is simply transferring molecular velocity of the gases into physical velocity of the pistons and the crankshaft, we will get a much clearer conception of what we mean by thermodynamics. If we boil down all of our present scientific knowledge, we come to a few fairly definite conclusions. One is that all the various phenomena of nature obey a few very simple elementary rules of mechanics. The laws of chemistry and physics and astronomy and all such matters are very delicately interwoven.

Let us analyze and find out what a charged particle is and what a catalytic reaction is, referring to the kinetic





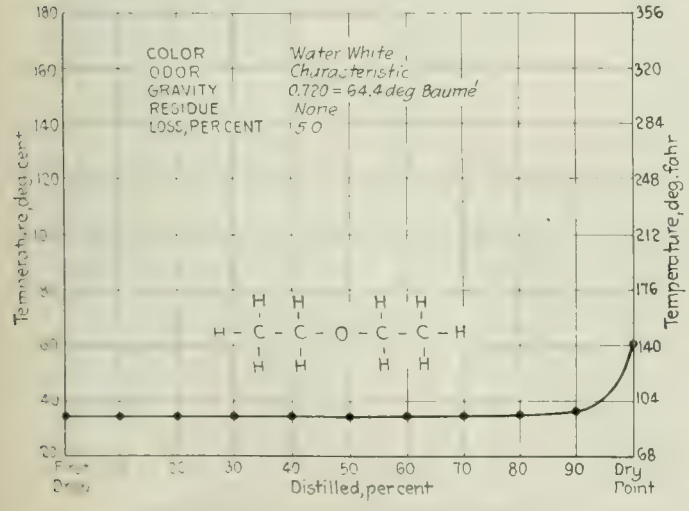
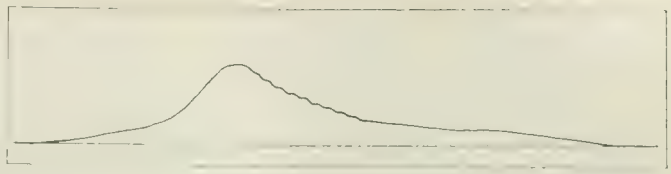
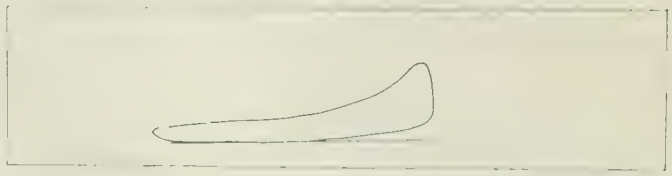


FIG. 8—FUEL STUDY OF SULPHURIC ETHER





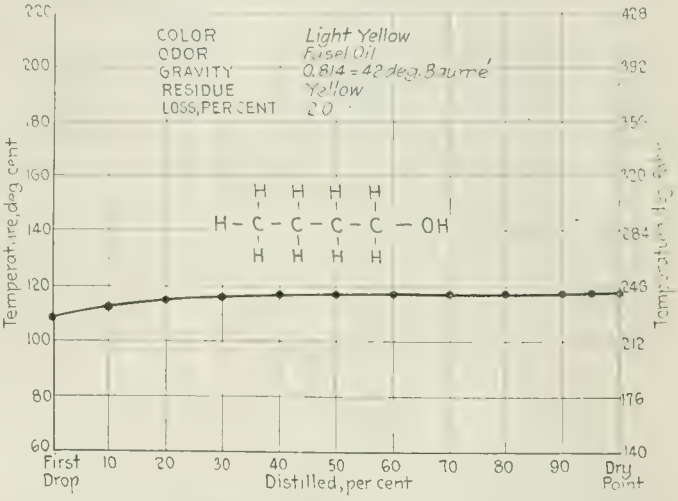


FIG. 9—FUEL STUDY OF BUTYL ALCOHOL

energy of combustion. The sensible heat in a gas is proportional to one-half of the energy, that is, to one-half the mass times the square of the velocity of the molecules of the gas. The various velocities have been measured. The hydrogen has a molecular velocity of 5560 ft. per sec. at 32 deg. fahr. (10 deg. cent.). The oxygen figure is approximately one-fourth of that. The water has a velocity which is the equivalent of the molecular velocity. The values of $\frac{1}{2}\ mv^2$ show us that we have left the difference between the sum total of all the kinetic energies of oxygen and hydrogen and the kinetic energy of the water vapor. That difference we have taken out is energy, so far as the slowing down of the gas particles is concerned, and that is a sensible amount of heat; it is 305 B.t.u. per lb. of hydrogen.

In reference to the barometric energy of combustion, this is just the difference due to the changing of volume. At 32 deg. fahr. and 14.7 lb. per sq. in. absolute pressure, 1 lb. of hydrogen occupies 180 cu. ft. and 8 lb. of oxygen occupies 90 cu. ft., a total of 270 cu. ft. But 9 lb. of water occupies 180 cu. ft. and the difference between the 270 cu. ft. occupied by the hydrogen and the oxygen and the 180 cu. ft. occupied by the water gives 90 cu. ft. as the reduction in volume upon the combustion of 1 lb. of hydrogen. Completing the analysis gives

$$(90 \times 144 \times 14.7) \div 778 = 245 \text{ B.t.u.}$$

This is the barometric energy of combustion of 1 lb. of hydrogen, and the 245 B.t.u. per lb. of hydrogen is not as much energy by about 30 per cent as was caused by the slowing down of the gas particles.

Fig. 3 illustrates the combustion of hydrogen and oxygen. What happens? First, we say that heat must

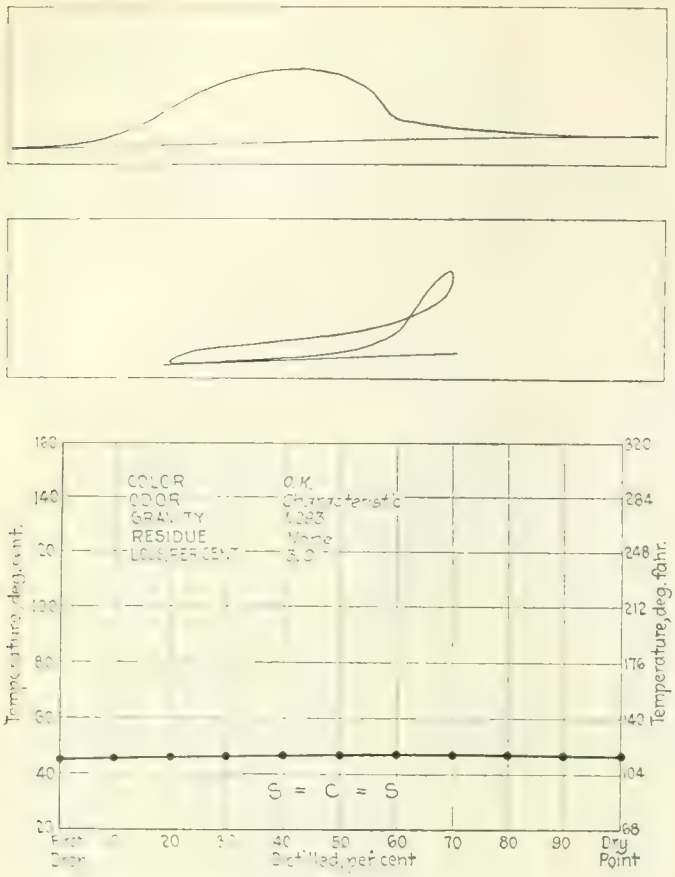


FIG. 10—FUEL STUDY OF CARBON BISULPHIDE

be supplied to break up the molecules. Let us not call it heat. Let us say that we must accelerate the velocity of that hydrogen particle to a point where its acceleration pressures are greater than its attraction. We have things here that are sticking together. We begin to shake the molecule back and forth and reach a point where the acceleration pressures become greater than the force holding the atoms together and they come apart. We have free hydrogen and free oxygen. Heat, *A*, must be supplied to break up the molecules as shown in Fig. 3; these unite and produce heat, *B*. That combination is given energy from the standpoint of kinetic energy, of barometric energy and of gravitational energy. So *B* minus *A*, gives the available amount of velocity or heat that we can use for something else. In this case it is 57,000 B.t.u. per lb. of hydrogen. The result is a liquid; it is water at 64.4 deg. fahr. (18 deg. cent.). I have followed through this rather elementary thing, the burning of oxygen and hydrogen, because I think that we as engineers should get acquainted with the problem in specific application rather than in perfectly general terms. We have been accustomed to putting the charge into an engine cylinder, saying that it exploded, and letting it go at that.

Fig. 4 illustrates the normal combustion of propane, which is a hydrocarbon gas. This is purely a theoretical expression. Instead of having a simple combination of molecular oxygen and molecular hydrogen, we have a combination symbolically represented as shown. This expression does not necessarily represent the facts in the case at all. When the hydrogen and oxygen unite, the same thing happens as when the molecular oxygen and hydrogen became one; so, there is a combination of energy represented here that may be many times greater than the simple energy of the hydrogen-molecule or oxygen-molecule combination. If we were using propane in an engine cylinder, the first thing we would need to do when a spark is put through it is to supply enough motion to that molecule to shake it apart, so that it becomes free hydrogen and free carbon. In the presence of oxygen, new gravitational conditions are set up and there are tremendous disturbances which we call heat. Calculating as before, the heat of combustion is 20,000 B.t.u. per lb.

We call that a normal combustion of hydrocarbon where the oxygen and hydrogen form water and the carbon and oxygen carbon dioxide. There is a condition under which we can bring oxygen, nitrogen and hydrocarbon together, where we do not get the perfectly normal combustion that results in water and carbon dioxide, but where the rapidity with which we accelerate these things is so great that we burn only a part. It is something like a load of bricks on a wagon; when we check the wagon too quickly the bricks slide off. In the case of an abnormal combustion, we start the one particle so fast that the other cannot follow. Then we get an entirely different result. In the abnormal combustion shown in Fig. 5, we get a much smaller amount of heat with the liberation of free carbon, instead of getting a large number of heat units as before. If we put propane gas into an engine, we would never get a condition of abnormal combustion such as this, nor would we get a knocking condition, because we would have in the engine a diluting element in the form of nitrogen gas. But if we change the mixture, if instead of air and propane in the engine cylinder, we throttle out the nitrogen and begin to let into it a little oxygen, we immediately meet the abnormal condition shown in Fig. 5. So, no matter how excellent the specific gravity of the fuel is, we can always reach an abnormal condition with it by accelerating the combustion.

THE NECESSITY OF THEORIZING

The matters I have explained thus far relate to the elementary mechanics of combustion. Any thermal chemistry contains the same information; there is nothing new about any of it. There is no trouble in getting this information; the trouble has been in the nomenclature which has been used. We use the terms "heat" and "light" without having a physical conception in our minds as to what these things really mean.

The theory of all of this may be 100 per cent wrong, but that makes no difference. If we never had theories about things, we would never arrive at radical results. To illustrate, Mr. Midgley and I had the very beautiful theory that what causes kerosene to knock is that it enters and becomes vaporized due to the heat that is in the cylinder when it comes in, and that when compression begins, the heat of compression does not develop fast enough to keep the kerosene from liquefying again and the mixture slows down to a point where the kerosene forms in little particles on the cylinder wall. We knew that early spring flowers are red on the bottom of the leaves, so as to utilize the maximum amount of radiant energy from the sun and get a little more heat. Therefore, we concluded that if we dyed fuel red it would absorb more energy and consequently not condense so easily. The chemical laboratory had no oil-soluble dye, but it did have iodine. Iodine colored our fuel red and that was all we wanted. The iodine stopped the knock, but it did not stop the knock because it was red. However, if we had not had that theory we would never have found out about these matters. So, I think we ought not

to criticize a man for having a theory. If he has no theory, he will not progress very far.

We know that very definite chemical laws govern existing fuels and that many things can be done in making use of them. This subject is presented with the idea of laying before automotive engineers what we have found out and what we are thinking about. We realize that we are so inadequately equipped, mentally and physically, to cope with all the ramifications of this problem, that we need to show the progress made from year to year and to get all automotive engineers to think along this same line. It makes no difference whether a single thing I have said is right or wrong. If I can convey the point of view of realizing that this problem exists, I shall be satisfied. I have been accused recently of trying to rewrite the theory of explosives. We are not trying to rewrite anything; we are simply trying to utilize facts. We know that engines knock. That is not a theory any more. It is a fact that we get crankcase dilution. We simply try to take the facts, analyze them, find out the cause and determine what can be done to eliminate it.

Anti-Knock Substances

The anti-knock substances are not nearly on a commercial basis as yet. They are more nearly on a commercial basis now than they were a year ago, because people understand the situation better. They have many other values besides that of stopping the knock; they are carbon solvents. We analyzed many carbon deposits. We found they were made up of free carbons, a very heavy hydrocarbon and a very small amount of a hydrogen-oxygen carbon, and that a binder which is about the same as an ordinary varnish holds this hydrocarbon and the free carbon together. It happens that these anti-knock substances are all varnish-removers; consequently they dissolve out the binder part of the carbon deposits and the remainder blows away.

There are many theories regarding detonation. Fig. 6 shows a piston taken out of a Liberty engine; the top is cracked. We have seen some pistons, worse than this one, that have been blown in. We do not know what hit the piston; an explosion-wave or a detonation. The fact is that the piston was knocked in.

Difference in Molecular Structure

We have a number of apparently dissimilar substances that have the same chemical constituents. Ordinary rubber, such as is used in automobile tires, and naphthaline are two apparently different substances. One is a very tough, tenacious material and the other is a crystalline substance; but each is composed of hydrogen and carbon. I mention them to show that the same two

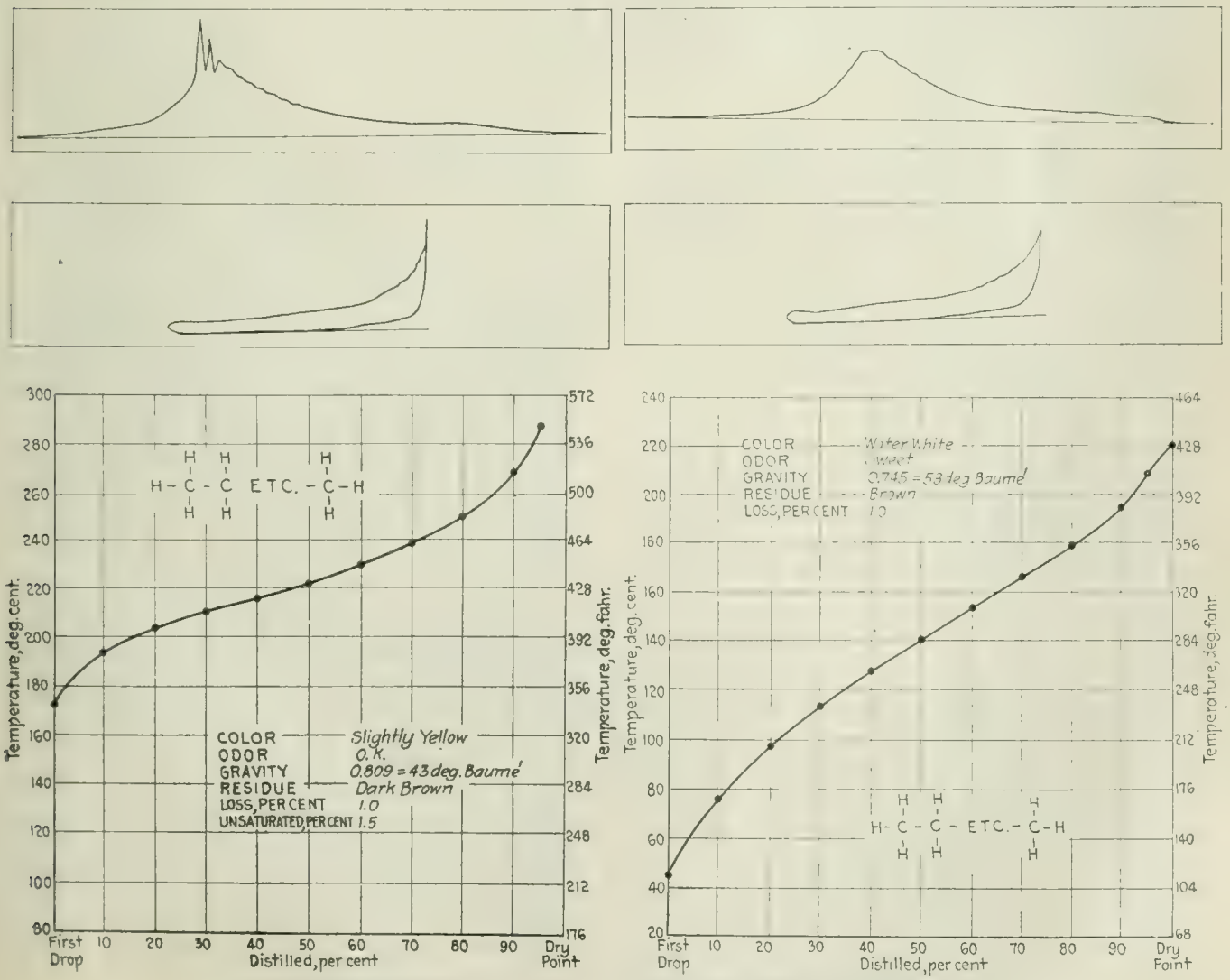


Fig. 11—Fuel Studies of Two Fuels Obtained from Pennsylvania Crude Oil
The One at the Left Is for Kerosene and That at the Right for Gasoline

things can be put together in such ways that their molecular constitutions are enormously different. Another instance is that of two liquids, benzol and cyclohexane, the latter being nothing but benzol with an added amount of hydrogen.

The crystalline substances, naphthaline, rubber and paraffin, which is a more or less amorphous form of hydrogen and carbon, are all the same; they are just made up in different combinations. That is why we must realize that the chemical constitution of fuels represents so many different things.

Ignition Point and Fuel Utilization

There has been much discussion as to the ignition point. The autoignition point is only the point at which we reach the proper condition of molecular velocity; it has absolutely nothing to do with the phenomenon of knocking. Carbon bisulphide has such a low autoignition point that we can heat it with a hot wire and explode it. If we put that into an engine, it absolutely will not knock, and yet its autoignition point is only 140 deg. So, autoignition, or preignition, has absolutely nothing to do with the phenomena we are talking about.

The question of the utilization of fuels to-day involves two distinct things. One is the matter of getting the right mixture into the cylinder. This has no relation to the physical constitution of the fuel, except insofar as it is hard to segregate and nebulize to get the right amount by weight of fuel and air into each cylinder. After

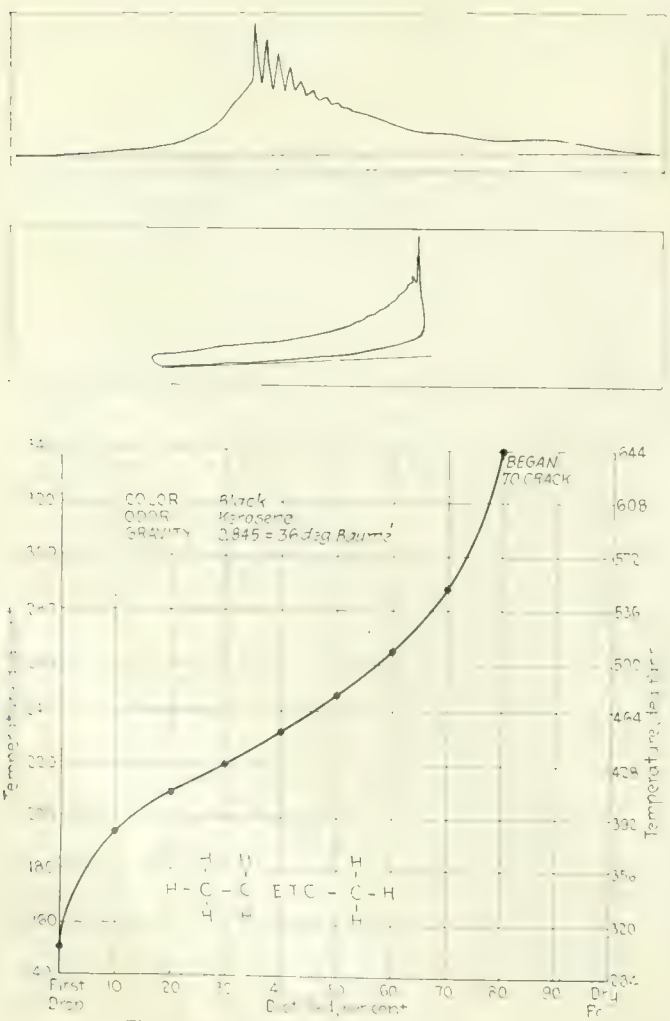


Fig. 12—Fuel Study of Fuel Oil

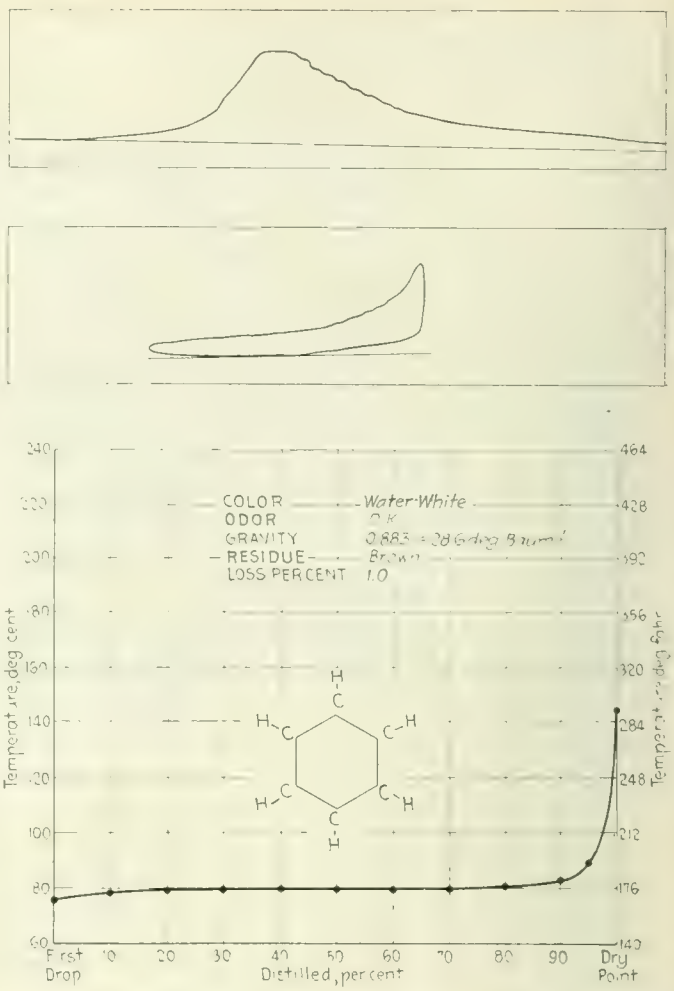


Fig. 13—Fuel Study of Commercial Benzol

experimenting with a single-cylinder engine, the very distinct conclusions are reached that it makes no difference whether the fuel goes in as a dry gas, a nebulized gas, a vaporized gas, or any kind of gas; that if we get the right weight of fuel and air into the cylinder the mixture will burn under certain definite conditions; that the conditions under which that fuel burns are a function entirely of its chemical constitution; that abnormal combustion, which we term "knocking," is an entirely different phenomenon from preignition; and that the autoignition point of a fuel may or may not have something to do with its knocking ability.

If we can only get it into our minds that we should quit thinking of heat in any other terms than those of molecular velocity, we will have helped ourselves one step farther along in our ability to realize and to bring together the loose ends of the fuel problem. All of the phenomena of physics and chemistry can be utilized in engines. It is only because we perhaps have not had to analyze the details of these operations, more than was necessary at the beginning of the automotive industry, that we have forgotten them. That has been perfectly natural in the development of this business. In the early days we had fuel of a high volatility. All that was needed was to make true engine cylinders, well fitted pistons and valves and then install almost any type of mechanism to supply the fuel. The engine ran very well. The volatility of the fuel began to drop and we began to

(*Concluded on page* 343)

The Relation Between the Highway and the Vehicle

By B. B. Bachman[1]

Washington Section Paper

AFTER reviewing briefly the general history of highway and motor-vehicle development, the author discusses highway and motor-vehicle relations in regard to the respective merits of constructing highways of relatively short mileage suitable for the operation of very heavy traffic and greater mileages of roads of a character that will make necessary the limiting of the vehicle load to protect them from undue deterioration. The maximum weights allowable for horse-drawn and for both light and heavy motor-vehicles are commented upon and the question of whether to have restricted or unrestricted motor-vehicle traffic is discussed pro and con.

The advantages of having adequate highways and suitable vehicles are reviewed and restrictive legislation in its relation to wheel loads and to interstate traffic is considered.

FOOD, shelter and clothing are the fundamental requirements of mankind, in the order of their importance. A human being can obtain each of these for himself to an extent that will support existence, independently of any assistance from others and even under rather adverse conditions. There are probably no examples of the individualistic savage extant. The next step from this individualistic state is the small community where the individuals divide among themselves the performance of those functions that provide for the composite need. The size of such a community is limited only by the ease and speed of communication. Even the most uncivilized peoples have progressed to the community state, although it may be in the crudest form. These communities remain small, limited in their prosperity, burdened with disease and filled with tribal jealousies so long as their means of communication are limited to messages from drum-beats or signal fires, or to the use of beasts of burden that travel over natural pathways. The military highways of Rome, the fleets of Venice and Genoa and Great Britain, the railroad, the automobile and the airplane are the means by which mankind has widened its perspective and, conquering the wilderness, has built up the system of industry which is the framework on which civilization depends.

The beast of burden is represented by sufficiently diversified types to make it possible to find one suited to almost any natural condition of terrain. In many cases beasts of burden can subsist on the products of the country through which they are traveling and their limitations of usefulness are therefore speed and fatigue. These limiting factors are reduced by the preparation of highways that need be only of a relatively elementary nature. But the railroad immediately enters the field of extensive preparation, that of the roadbed involving for most economical operation suitable capacities of rails and ballast, a limitation of gradients and adequate bridges. The manner in which these requirements are met varies with conditions. To meet them in a manner requisite for main-line construction necessitates a large investment of capital that, naturally, is justified only when the anticipated earning power will insure a sufficient return. It is for this reason that the early days of railroad building in the United States witnessed the construction of many miles of roadbed that was ridiculously crude when viewed in the light of present traffic conditions. The need at that time was not for a few miles of high-grade construction, particularly in the transcontinental field, but for a large mileage of anything that would serve the immediate need, awaiting the development of the Country with a coincident growth of traffic that would warrant a greater investment. Even today there are numerous miles of branch lines on which the traffic density does not warrant the highest type of main-line construction. Manifestly, the same weight of trains cannot be used on these lines, nor can the same speeds be attained as on the main lines. Under present-day conditions, therefore, we find heavy equipment operating in the dense traffic zones of the railroads at high speeds over easy grades having heavily constructed roadbeds, and lighter equipment operating at more moderate speeds on branch lines and feeders.

The advent of the automobile in this Country found road development in the areas outside of metropolitan districts almost at zero. All of us whose automobile experience dates back even 10 years have been bumped over water-breaks, mired in hub-deep mud and stalled in snow-banks. Gradually, the construction of roads has come about here and there throughout the Country that has made automobile travel a comfort and a delight. These road improvements have consisted in greater part of providing a reasonably hard, smooth surface. In some places grades have been lessened and sharp turns and dangerous crossings eliminated. The requirements for this class of traffic are for a highway wide enough to permit passing other vehicles at a reasonable speed, a surface that is smooth but not slippery when wet, and a strength of road and bridges sufficient to support passenger cars on pneumatic tires. Furthermore, the rapid increase in the use of these vehicles in suburban and rural districts has created in almost every locality a demand for highways improved in this manner. This has resulted in a need for the construction of an apparently staggering amount of road mileage. The cost of this construction naturally depends upon its nature, and this in turn depends upon the character of traffic that will use it.

Following the development of the passenger vehicle, the automobile industry, aware of the demand for this apparatus as a transporter of merchandise, entered the field of commercial-vehicle manufacture. In the beginning, we find the truck appearing as a relatively small vehicle for delivery purposes and timidly reaching out to extend the radius of operation beyond the zone to which it had been limited by animal-drawn vehicles. Then came the development of the heavier vehicle principally used in hauling larger shipments over comparatively short distances, mostly within city limits. Examples of its use are deliveries from wholesale warehouses to retailers of building materials and the like. The successful operation of these earlier and lighter-type commercial vehicles created a demand for larger vehicles, the build-

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ing of which was made possible by the coincident advance in knowledge of mechanical construction. At the same time the increased radius of operation over that of horse-drawn vehicles, made possible by the use of light commercial vehicles, resulted in the demand of operators for the use of the heavier vehicles in competition with railroads. One of the earliest instances of this sort of competition was the transportation of furniture and household goods by motor van over distances of several hundred miles.

The congested condition of railroad facilities during the war furnished the opportunity to put the motor truck to the acid test as a tool for long-distance transportation. We are all proud of the accomplishments recorded; nevertheless, many things were done during that period of necessity that are not warranted by strict considerations of efficiency and economy, and many problems were brought to the attention of the builders of trucks and of highways, of the general public as well.

Highway Development

We, as a Nation, had gradually progressed from the ordinary dirt and loose-stone country-road to improved highways of various types in the more thickly populated States and in the vicinity of large cities, but these roads had not been put to the task of carrying modern truck traffic. It was therefore a rather rude shock to note the condition of some of our pet roads after the winter of 1917-1918. It is only natural that observers of the condition should react differently and largely in accordance with their interests. The taxpayer, the operator of passenger vehicles and the departments charged with maintenance and construction of roads have, in many instances, expressed the opinion that a limitation of loads is essential. The builders and operators of motor trucks have advocated consideration of the vital necessity of constructing more durable roads, the character of which would permit the operation of heavy vehicles upon them, and to support their contention have pointed to the many economic factors favoring such operation. Undoubtedly, there are meritorious features on each side of these arguments, and it is highly probable that the true solution for the present at least lies somewhere between the extremes.

The question that we are facing today is whether we shall spend the money that is available in the construction of relatively few miles of road suitable for the operation of very heavy traffic, or in the construction of a greater mileage of roads of a character that will make necessary the limitation of the vehicle load to protect them from excessive deterioration. This is in many respects the same problem that faced the Country in the early days of the railroad, and an analysis of it requires answers to a number of collateral questions.

Probably the first question is, Who will be the users of these roads? Horse-drawn vehicles are slow-moving, equipped with metal-tired wheels and, in the heavy class, in many instances unsprung. They are disappearing rapidly in the industrial districts and will probably continue to disappear at an accelerated rate. They may be replaced to a large extent in agricultural districts by motor vehicles for passenger conveyance, but still are being used to a large degree for other purposes. While the motorization of the farm is in progress, a long time will be required to displace the horse, even with a greatly increased production of motor vehicles. Therefore, viewing the matter on a national basis, it seems that this class of traffic is of great importance.

The maximum weight of a horse-drawn equipment is probably not over 12,000 lb. except in rare cases. A road equipped with bridges capable of sustaining this load, with a surface that will provide a footing for the animals in bad weather and of a character to resist the chipping action of hoofs and the cutting of metal tires, will meet, speaking generally, the requirements of this class of equipment.

Light motor-vehicles as a class include both passenger cars and trucks up to a maximum weight of 12,000 lb., with their burden. All passenger cars and trucks up to this capacity to an increasing degree are being equipped with pneumatic tires and with adequate spring-suspensions. The road requirements for this class of vehicle are in most respects similar to those of the first class, the only difference in operation being with regard to speed. It is very probable that the difference in tire and spring equipment will balance the last named factor to a large degree.

The heavy class includes motor-vehicles of a gross weight of from 12,000 to 20,000 lb. This class is to a large degree equipped with solid tires and also, as in the case of the second class of vehicle, with adequate spring-suspension. Vehicles in this class of from 3½ to 4-ton, and 5-ton capacity in some cases, are transportation units that, while having great efficiency and proved usefulness, are still within the weight limits that do not make necessary the construction of roads of extremely high capacity.

Finally, as a fourth class, we have the larger trucks of 6 to 7½-ton capacity that will weigh from 26,000 to 30,000 lb. with bodies and load. While these sizes of unit have proved to be of considerable value in solving many transportation problems, the operation of the vehicles at high speed, particularly in the late winter and spring months, has resulted in great damage to many roads not of the very highest type of construction.

Restricted or Unrestricted Traffic?

This condition has aroused the feelings of the other users of the highways, and caused the authorities charged with highway supervision to look with some disfavor on this class of traffic. Recent legislation has taken cognizance of this fact, and we find that in many States a limit of 28,000 lb. is set as the maximum total burden for one vehicle, and in some States less than that. At the same time, the highway authorities in some States have availed themselves of the authority vested in them to make temporary restrictions effective for the winter months that reduce this limit to still lower figures. These restrictions cause no inconvenience to the first three classes of road user, but naturally the user who is restricted in his operation is very much disturbed and also the producer of this apparatus is concerned, as it may take the form of reducing his sales.

Many plausible arguments are presented to the effect that roads and bridges should be constructed with sufficient capacity to accommodate a relatively unrestricted traffic. It is pointed out that in the last few years the transportation of merchandise by trucks over relatively long distances was all that prevented the acutely congested condition of the railroads from causing an industrial calamity. While it is generally agreed that under normal conditions it is unlikely that the truck can compete with the railroad for distances of over 50 to 100 miles, dependent upon conditions as to climate, road, topography and the like, still it is argued that, in view of the insurance factor, if adequate highways were in existence in case of a recurrence of conditions such as existed during the war, we should make our plans with these things in mind. Then the question of the military value of roads is presented, and the necessity of giving

due consideration to the part that highways and truck transportation played in the critical periods of the war, notably in the defense of Verdun and Paris. All these arguments contain a considerable amount of logic and no one can doubt their force. There is this fact that must be considered, however: The problem we are contemplating is largely one of immediate necessity and not of future requirements. If we had a great mileage of adequate roads in this Country and were considering what we should build for the future, or if we were studying the construction of a direct revenue-producing system such as a railroad, these factors could be considered in a different light. But we are far from having even an approach to an adequate highway system, considering the matter nationally, and the question of finance is serious in these days of high taxation. The great need for heavy-capacity roads is to a large degree in the industrial areas, but the taxes would fall with equal weight on the small community and the farmer. Rural people are in many cases annoyed by dust and water-breaks in summer, and by having to flounder through mud in winter. They demand relief and care little how great the capacity of the road is, so long as it endures and supports their passenger vehicles and trucks.

In view of all these factors and for the best interests of all, it seems that the logical answer to the question is to build roads, to the limit of our resources of labor, material and money, of such a character as will secure the greatest mileage, and of width and carrying-capacity consistent with the needs of present traffic and that of the immediate future. For metropolitan areas such a program should provide roads capable of caring for vehicles of from 26,000 to 30,000-lb. overall weight, with a possible limitation to a lower figure in the winter months or whenever local conditions make such action temporarily necessary to save the roads. Between large industrial centers that are relatively not far apart, such as those along the Eastern seaboard and along the shores of the Great Lakes, there should be trunk-lines of the same character. Outside of such areas of dense population, where the volume of traffic is smaller, trunk-lines connecting and forming through routes of sufficient capacity for medium-weight vehicles, not over 20,000 to 24,000 lb. gross, should serve admirably. Connecting and community roads in the great rural areas, if constructed on the smaller-capacity basis of 15,000 lb., should be entirely adequate in comparison with present facilities.

As to what the result would be if such action were taken, from the standpoint of the effect on the user and the communities through which these improved highways would run, a complete list of the benefits would probably sound like a fairy tale. It is only necessary, however, to view the change in conditions that has resulted from improved highways to see that life in rural communities has become more attractive because of the increased opportunity for social intercourse. Farms are improved on account of the possibilities of transporting their products to more profitable markets; and such conditions result in many cases in the reoccupation of abandoned farms and their being brought again into a state of active production. From the standpoint of education, the influence of good roads has resulted frequently in the consolidation of small schools, the pupils being transported by omnibuses. This has had the effect of creating a community spirit, increasing the efficiency of the teachers by making possible the grading of the pupils in a more modern and efficient way, and insuring continuous schooling for many children, which was impossible under the old conditions. With regard to the motor-car builder and distributor, those in the passenger-car and medium-duty-truck fields would be greatly benefited. The heavy-duty-truck field also would be broadened, possibly not so much as those directly concerned might wish, but still to a considerable degree. Another phase of the last named consideration is that, given a more general distribution of roads of the nature outlined, it will be possible to increase the ratio of burden capacity to vehicle weight. This is true of all classes of motor vehicle. The reserve power and strength that must be provided to cover present road conditions could, and undoubtedly would, be reduced materially if hard, smooth-surfaced roads of relatively low gradients were common. Such a condition would go a long way toward reducing operating expenses, due to more efficient returns from expenditure for fuel, tires and the like, and to reduction in maintenance and repair costs.

Present Highway and Vehicle Needs

To sum up the whole matter, as a Nation we need thousands of miles of roads. These roads are an immediate necessity and should be constructed as a result of careful, broad-minded, constructive planning. Many roads that have been constructed at great expense have no economic justification for their existence, and many communities are still laboring under the handicap of inadequate roads. In road construction the linking up of industrial areas should be taken into consideration. Consideration should be given also to providing agricultural districts with outlets to profitable markets. Long-distance highways of expensive construction that serve no economic purpose should have no place in our present plan. The creation of such a system will require a concentration of our resources of labor and money to the utmost to meet the urgent immediate necessities. It is necessary, therefore, that the problem be considered from a national viewpoint with the legitimate needs of everyone in mind, and without the entrance of any taint of class consideration.

In many communities where the cost of road construction is apparently an unsurmountable obstacle, the real difficulty probably lies in the fact that taxpayers as a body feel that the road improvements that are being demanded will minister to only a limited class. The fallacy of this viewpoint can be demonstrated readily by a comparison of the speed capacity of horse-drawn and motor-driven vehicles. The transportation radius can be increased from two to four times, or the time occupied in covering a given distance can be reduced to one-half or one-third when motor-driven replace horse-drawn vehicles. The economies that can be effected, together with the increased profits that can be made by reason of this saving in time, will more than justify the cost of the construction. Outside of the industrial-district and trunk-line construction already mentioned and in view of the road and bridge requirements considered ample for animal-drawn traffic, it does not seem that a much more expensive type of road is necessary to serve the needs of motor traffic, and what increase in cost there is will be amply justified in the light of what has been said. On the other hand, it does not appear to be justifiable to attempt the construction of roads of a capacity capable of carrying the extra-heavy motor-vehicle traffic everywhere regardless of conditions, for such a procedure will not only entail unnecessary expense but tend to retard the construction of vitally necessary roads, on account of the opposition that such a program would encounter. With a rationally graded system of road construction, the truck as an efficient tool of commerce can be developed along

lines that will be consistent with such a program, without hampering either the manufacturer or the user in their respective fields.

Restrictive Legislation

There is a crying need for the coordination of legislation relating to the control of highways and traffic, particularly interstate traffic. This probably will be secured only under Federal supervision. In many instances highways that are excellent within a State's boundaries are neglected near the borders or do not connect with similar roads in adjacent States, thus breaking down the possibility of through traffic. Another factor is the specification of allowable load per wheel and per inch of tire width. With regard to the wheel load, this is entirely proper because it provides information that the highway engineer must use in estimating the requirements of foundations and the beam strength of the road. It is essential that the specification should be on uniform lines in all States. The provision with regard to load per inch of tire width seems to me to be based entirely on false premises, and the way in which it is applied at present is wrong. Solid tires have the greatest width when worn down to the base, and yet there is so little cushioning effect when they are in this condition that they are much more harmful to the road than a narrow tire with sufficient thickness to provide a cushion. This seems self-evident, and still we find the per-inch-width-of-tire provision in almost every law, with varying methods of application, and practically no provision against the use of worn-out tires that are harmful not only to the roads but to the vehicles as well.

ACCURATE THREAD-CUTTING

IN tapping holes for ordinary screws, such as those used in holding machine parts together, good fits are chiefly dependent upon the accuracy of the tap. As the tap is generally a rigid tool and non-adjustable, it will tap a hole approximately to its own size; but when the lead has been found to be inaccurate, due to distortion in hardening, there has been in the past no practical means of correction to bring the tool back to its original condition of accuracy. Dies used for threading screws are generally adjustable as to diameter, and because their chasers are short, they are easier to control in hardening. For this reason screws with fairly accurate leads can be cut with commercial dies.

Absolute accuracy of the lead in taps is unknown, and even the diameter and shape of thread is very hard to maintain. Tolerances are therefore established on fits between the threaded parts. By the use of such equipment as the Hartness comparator it is a simple matter to determine the accuracy of the lead of threaded parts.

Lead of the Screw

When the lead in a nut varies from the lead in a screw, there is hardly more than one thread in contact. When the nut is tightened, this one thread yields until one more thread is in contact, and by further tightening it may be possible to get a number of threads to assist in carrying the load. However, the engagement between the threads of the nut and the screw extends over only part of the length of the thread in the nut; and where there is contact, the threads have been distorted. When the screw is exposed to the load, due to the pressure brought upon it by the machinery parts that it is supposed to hold together, it is liable to work loose, because of insufficient contact between the threaded parts.

It is often attempted to overcome this difficulty by employing lock-nuts as substitutes for accuracy in the threads. Fine-pitched threads are easier to force into contact with each other than coarse-pitched ones; but the finer threads are also easier to destroy, and when the two parts are hardened, these finer threads are often broken off altogether. The original trouble of the wrong lead of thread has never been fully overcome by the employment of any substitute. On the other hand, if the lead in the nut and the screw are the same, all the threads in the nut are in contact with the screw. In tightening the nut, no yielding will take place, and the friction obtained throughout the length of the thread will keep the nut from vibrating loose or the thread from yielding. Even if a nut fits loosely on the screw, but has the same lead as the screw, it will hold tightly with moderate pressure.

Every experienced engine-builder has had trouble in fitting studs into cylinders and similar parts. The stud is screwed into a tapped hole. Generally it fits loosely into the first threads and tightens after being screwed in further. The tightening is due to the difference of the lead in the two members, and it is taken for granted by the workman that he has a good tight fit. When the cylinder head is mounted and the nuts tightened on the stud, the threads of the stud in the casting will yield under the pressure; but when the cylinder head is to be removed and the nuts are taken off, it is often found that the stud will come out with the nut instead of staying in the tapped hole in the cylinder. If the lead of the thread in the hole and on the stud were the same, the stud could be made to fit throughout the length of the hole and every thread would then do its part in holding the stud firmly in place.

The methods for making gages for measuring and inspecting screws have developed considerably during the last fifteen years. When good work is required, the screw-maker is held down to very close limits. In many cases not even a maximum and a minimum gage are used for testing a screw-thread. The screw in that case is expected to fit with an even friction in only one gage. As the die is adjustable, it is possible to meet this requirement. But is it not incongruous that after having made all of these fine screws and inspected them with this very fine gage, they are put into holes that are tapped with a tap that often has a thread with an inaccurate lead, and that has a fairly large tolerance on its diameter? Furthermore, all of the holes for these fine screws are not always tapped with the same tap, and when screws are made to fit fairly satisfactory in a hole tapped with one tap, they will not fit a hole tapped with another tap, although the taps are supposed to be of the same size.

In addition, taps are often slightly bent in hardening, the lead being a little longer on the convex side than on the concave side; and although the diameter may be fairly close to size, as measured with a ball micrometer, it will not tap a hole of the same size as its own diameter on account of being bent. I have had the experience with taps measuring very nearly the same in diameter, of one tapping a larger hole than the other because it was straighter than the other. I have come to the conclusion that the majority of difficulties in thread-fitting are due to the inaccuracy of taps. If taps are made accurate in lead and diameter, most of the troubles encountered in fitting threaded parts are likely to be overcome.

Great efforts have been made by committees of experienced men to eliminate the errors in the various types of thread-cutting tools; and great strides have been made in establishing tolerances within so-called "commercial limits." If the market can be supplied with an accurately made tap, this problem will solve itself; and if screws and threaded holes can easily be held to a predetermined size, according to standards in vogue, the committees will be relieved of the task of establishing tolerances that will suit everyone's requirements.—B. W. M. Hanson in *Machinery*.

Automobile Frame Stresses

By Ethelbert Favary[1]

Metropolitan Section Paper *Illustrated with* Diagrams

FOLLOWING a review of some of the factors that are productive of excessive weight in a motor vehicle, which causes fuel wastage, and a statement that a more thorough standardization of frames and other parts would eliminate much of this waste, the author presents in detail frame-stress calculations intended to enable the designer to proportion frames and parts with this end in view. Shearing stresses are treated in a similar manner and for a similar reason, use being made of diagrams that facilitate analysis of specific instances cited and being inclusive of a table of bending-moments derived from the diagrams.

Laboratory tests of the ultimate strength, elastic limit, yield-point, elongation and reduction in area of materials are then described in some detail and the results obtained stated.

THE stress in the metal of channel frames varies greatly in trucks produced by different firms and also in the several models of the same builder. Trucks of the same capacity having vastly different wheelbases often are found to have channels of the same size. It is true that sometimes a better grade of steel is used by the maker in his trucks of larger capacity when the section is kept the same. Obviously, if the stresses in the frame are not too high for a 7½-ton model, the frame of a 3½-ton truck, having a channel of the same cross-section, is certainly too heavy. It can be argued, however, that the builder has certain dies for forming the channels and that it is less expensive to construct a 3½-ton truck with a heavier frame than to have new dies made for a lighter frame. This may be true, but it means more dead-weight for the same carrying capacity. What is true of the frame is true of other parts of the machine, and the amount of excessive weight often is considerable, implying a constant waste of fuel and material that might be saved. It would seem that a more thorough standardization of frames and other parts would eliminate much of this waste. The Society of Automotive Engineers is doing excellent work in this direction, and the more readily producers cooperate with the Society, the more the automotive industry will profit.

Frame-Stress Calculations

The calculation of frame stresses, although simple, is a puzzle to some. This paper is taken from the regular lessons that are given to the second-year students of motor-vehicle engineering at Cooper Union.

Consider a 2-ton truck with a wheelbase of 148 in. and having the loads located as shown in Fig. 1. The 4000-lb. load and the body weight of 960 lb. are distributed over a frame length of 124 in.; one-half of this weight, 2480 lb., is resting on each side-member. The load is not always evenly distributed in practice, but it can be so considered for present purposes; but it should be remembered that the factor of safety must be sufficiently high to compensate for uneven load distribution. The driver's seat is 10 in. in front of the body and the gasoline tank is located underneath it. Assuming two persons and the gasoline to weigh 400 lb., we have one-half this load, 200 lb., on each side-member. The unit powerplant, with radiator and water, is assumed to weigh 1000 lb., 60 per cent of which rests on the rear supports and 40 per cent on the front, the radiator being situated above the front engine support; hence, 300 lb. and 200 lb. respectively are resting on each side-member at the points indicated in Fig. 1. This does not include the load due to the torque when applying the brakes and locking the wheels, which will be referred to later. Thus we have a total load of 3180 lb. on each side-member, supported by two semi-elliptic springs.

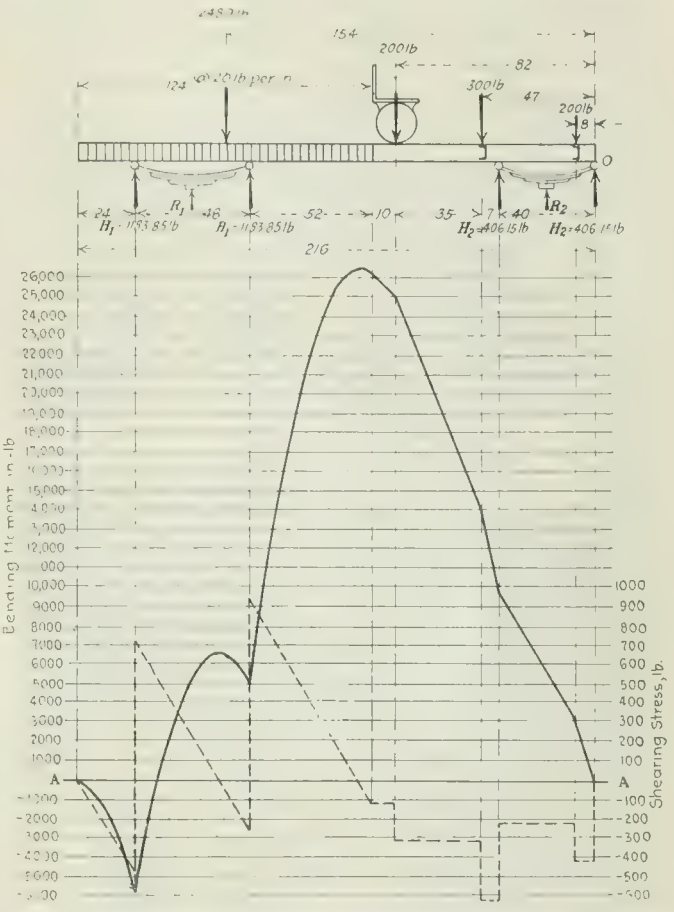

Fig. 1—Graphic Chart of the Frame Stresses in a 2-Ton Truck Having a Wheelbase of 148 In., and a Load Distribution as Indicated in the Upper Part of the Illustration

The first step is to find the reaction at each spring-eye.[2] The distributed load and the body weight are considered for this purpose as being concentrated at their center of gravity, which is 62 in. from the rear end of the frame; as stated, their weight on each side-member is 2480 lb. Denoting the reactions that are exerted

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[2] See the *Automobile Engineer*, August, 1912, p. 233, for an analysis of frame stresses by C. F. Cleaver.

against the frame through the spring-eyes by R_1 and R_2 respectively, the load on each side-member is

$$R_1 + R_2 = 3180 \text{ lb.} \quad (1)$$

Taking moments about the point O at the front, by the principle of moments

$$168\ R_2 + 20\ R_2 = (154 \times 2480) - (82 \times 200) + (47 \times 300) + (8 \times 200) = 414{,}100 \text{ lb.-in.} \quad (2)$$

Thus we have two simultaneous equations, (1) and (2)

Solving equation (1) for R_1 gives

$$R_1 = 3180 - R_2$$

Substituting this value for R_1 in equation (2), we write

$$168\ (3180 - R_2) + 20\ R_2 = 414{,}100 \text{ lb.-in.}$$

Then

$$534{,}240 - 148\ R_2 = 414{,}100 \text{ and } R_2 = 812.3 \text{ lb.}$$

In a similar manner R_1 equals 2367.7 lb. or R_2 can be deducted from the total weight to determine R_1. Since we have in this example two half-elliptic springs supporting each side-member, with the axles located centrally between the spring-eyes, the reaction at each spring-eye is taken at one-half the values derived for R_1 and R_2 respectively, or 1183.85 lb. at each rear spring-eye and 406.15 lb. at each front spring-eye, as shown in Fig. 1.

The next procedure is to determine the bending moments at various points along the frame. To make the diagram fairly accurate, the bending moments are determined at each 6 in. of the entire length. The 2-ton load and the body weight are considered as being evenly distributed over the 124-in. length and so 2480 ÷ 124 = 20 lb. per in. In practice, the frame weight per inch of length can also be included to insure greater accuracy; also other concentrated weights that may be suspended from the frame. The bending moment M at any vertical section of a beam equals the algebraic sum of all the moments of the external forces about that section, acting either to the right or to the left of the section. Table 1 gives all the values so calculated, but the bending moments are worked out for a few points to clarify the method for those who are not familiar with it.

TABLE 1—BENDING MOMENTS FOR EACH 6 IN. OF LENGTH IN FIG. 1

Distance from Left End of Frame, in.	Bending Moment, lb-in.	Distance from Left End of Frame, in.	Bending Moment, lb-in.
6	— 360.0	114	26,308.0
12	— 1,440.0	120	26,474.0
18	— 3,240.0	126	26,185.0
24	— 5,760.0	132	25,287.0
30	— 1,897.0	138	23,813.0
36	1,246.0	144	21,940.0
42	3,669.0	150	20,066.0
48	5,372.0	156	18,192.0
54	6,356.0	162	16,318.0
60	6,619.0	168	14,444.0
66	6,162.0	174	11,071.0
72	4,985.0	180	9,021.0
78	10,191.0	186	7,785.0
84	14,677.0	192	6,548.0
90	18,443.0	198	5,310.7
96	21,490.0	204	4,073.8
102	23,816.0	210	2,436.9
108	25,422.0	216	0.0

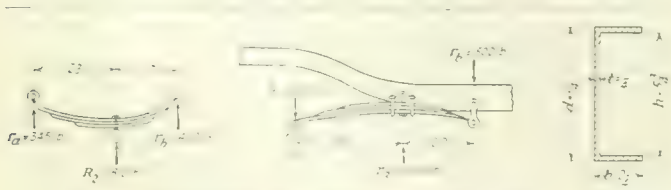


FIG. 2—DISTRIBUTION OF LOADS ON VARIOUS TRUCK PARTS From Left to Right These Are a Front Spring, a Half-Elliptic Cantilever Spring and a Frame Channel

The moments which would tend to produce clockwise rotation on the left of the section are taken as being positive, and those tending to produce counter-clockwise rotation as being negative. The reverse of this is true when the moments on the right of the section are considered. Beginning at the left and up to the first spring reaction R_1, the moments can be calculated from the formula for uniformly loaded cantilever beams.

$$M = \tfrac{1}{2} LW$$

where

M = the bending moment
L = the length of the cantilever beam up to the point at which the bending moment is to be determined
W = the total weight on the cantilever beam up to that point

Over the first spring-eye reaction r, we have

$$M = -\tfrac{1}{2}\ L\ W = -[\tfrac{1}{2} \times 24 \times (24 \times 20)] = -5760 \text{ lb-in.}$$

Beyond the 24-in. point, to the right, the moments due to the reactions must be considered. At 42 in. from the left we have, in addition to the negative moment, the positive moment due to the spring-eye reaction r_1. Thus,

$$M = -[\tfrac{1}{2} \times 42 \times (42 \times 20)] + 18r_1 = 3669 \text{ lb-in.}$$

At 84 in. from the left we have

$$M = -[\tfrac{1}{2} \times 84 \times (84 \times 20)] + 60r_1 + 12r_1 = 14{,}677 \text{ lb-in.}$$

It is in this manner that all of the figures in Table 1 were obtained. From these values the bending moment diagram is drawn, as shown by the full-line curve in Fig. 1. The vertical or ordinate values are laid off to some convenient scale. Each space in Fig. 1 represents 1000 lb-in. The bending moment at every point of the frame is evident from a glance at this curve. The ordinates above the base line AA represent the positive moments; those below represent the negative values.

When the axle is not at the center of the spring, that is, with offset springs such as are used frequently with front suspension, moments must be calculated to ascertain the reactions between the spring-eyes and the frame. Let us suppose the case of a front spring eccentrated as shown at the left of Fig. 2, in which the axle is 17 in. to the rear of the front spring-eye. By taking moments about r_a we have

$$40r_b = 23R_2$$

so that

$$r_b = (23 \times 812) \div 40 = 467 \text{ lb.}$$

and

$$r_a = 345 \text{ lb.}$$

When calculating the stresses in a frame, the reactions must be established carefully to obtain accurate results.

With half-elliptic cantilever springs, the reactions at the frame supports may be considerably higher than the axle reaction. Taking the example shown in the central drawing of Fig. 2, where this type of spring is attached to the frame at a point 30 in. from the axle and the other end is anchored to the frame 20 in. from the spring-bolt, assuming that the axle reaction R is 1000 lb., moments are taken about the front end r_b to find the reaction at r_a. Thus,

$$50 \times 1000 = 20r_a$$

and

$$r_a = 50{,}000 \div 20 = 2500 \text{ lb.}$$

Since r_b will act downward like an extra load on the frame

$$r_b = (30 \times 2500) \div 50 = 1500 \text{ lb.}$$

Thus it is evident that the type of spring employed has an important bearing on frame stresses.

Shearing Forces

In a frame channel, only the vertical shearing stresses need be considered. The magnitude of the shearing force at any vertical section of the frame is the algebraic sum of the shearing forces acting on either side of that section.

The shearing stresses at one point are worked out to show how the values were obtained from which the shearing-force diagram, shown by the dotted lines in Fig. 1, is drawn. At the front spring-eye of the rear spring, 72 in. from the rear of the frame, the total load tending to cause a negative shear of the section is $72 \times 20 = -1440$ lb. At the left of the section we have the positive shear of 1183.85 lb., the first reaction, and $-1440.00 + 1183.85 = -256.15$ lb., and at the right of the section the shear is $-1440.00 + 1183.85 + 1183.35 = 927.70$ lb.; hence, at this section the shearing stress changes from negative to positive. Attention is called to the fact that at the maximum bending moments the shear is always zero. The stresses in the frame metal can be determined from the bending-moment diagram when the dimensions of the channel are known. The stress in any layer of a beam varies directly as the distance from the neutral axis, the maximum fiber stress being in the upper and lower flanges of the channel. Knowing the moment of resistance or the bending moment M at any section of the channel, the maximum stress can be determined from the well-known formula

$$M = SZ \text{ or, } S = M/Z$$

where

S = the maximum fiber-stress per square inch in the section

Z = the section modulus

Let us suppose that the channel used in this frame is of the section and dimensions shown in the drawing at the right of Fig. 2. The section modulus of a channel is given in most engineering handbooks and, in reference to the drawing at the right of Fig. 2,

$$Z = [bd^3 - h(b - t)] \div 6d$$

Substituting the dimensional values given in the diagram at the right of Fig. 2 and solving this equation, $Z=4.5$.

The maximum bending-moment is at a point about 120 in. from the left end of the frame as shown by the diagram. Here $M=26{,}474$ lb.-in. and the maximum stress is

$$S = M/Z = 26{,}474 \div 4.5 = 5900 \text{ lb. approximately}$$

However, it must be remembered that this stress of 5900 lb. in the outer fiber is induced when the load is static on the frame as shown. The springs sometimes will be deflected to about twice their static deflection due to impact under running conditions, or as much as their clearance will allow and, since the deflection in a spring is proportional to the load, the load on the frame must be assumed to be double the normal load shown. Hence, the bending moment, and consequently the maximum stress in the frame, are at least double the amount that has been stated.

The stress is considerably more when the frame hits the axle, as it does sometimes, and the load on the frame arising from the torque-arm or torque-tube when applying the brakes may alter the stress distribution in the side-members very materially. Taking the stress at twice the amount that has been calculated gives a maximum stress of 11,800 lb. per sq. in. If the ultimate strength of the material is 60,000 lb. per sq. in., the factor of safety is approximately $60{,}000 \div 11{,}800 = 5.1$. This is none too much when the overloads to which a truck is subjected are considered, and when the fact that the load on the frame due to the torque, when the truck is being stopped with the wheels locked, was not taken into account. In practice this load should be considered.

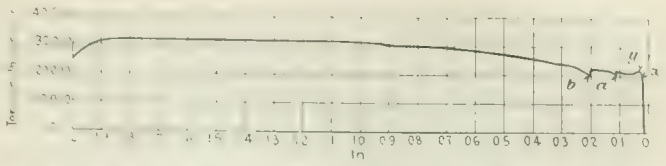


Fig. 3 Chart Showing the Results of a Laboratory Test on a ⅞ In. Wrought-Iron Sample

By studying the bending-moment diagram in Fig. 1 one can see at a glance where the frame can be lightened without sacrificing strength. The shearing stress is greatest near the spring-shackles; the maximum is less than 1000 lb. per sq. in. in the example given. The ultimate shearing strength of this quality of steel is about 50,000 lb. per sq. in., hence the section given as an example is ample. There is more danger from a crumpling of the web than from a shearing of the metal.

Laboratory Tests of Materials

We have made laboratory tests of the ultimate strength, elastic limit, yield-point, elongation and reduction in area on an Olsen testing machine. This is provided with an attachment that automatically draws a curve showing the elastic limit, yield-point, elongation and ultimate strength, such as is shown in Fig. 3.

A wrought-iron sample ⅞ in. in diameter and having an area of 0.6013 sq. in. was tested. Its tensile strength was 32,000 lb., approximately 53,000 lb. per sq. in. Its elastic limit, shown at x, is 20,000 lb., approximately 33,200 lb. per sq. in. The yield-point, shown at y, is 22,000 lb., about 36,600 lb. per sq. in. and it is evident that at y the deformation or elongation begins to increase rapidly. The machine was stopped for a few seconds at a and at b. In following the continuation of the curve the large increase in length for a very small increase in load should be noticed, until rupture finally occurs at a load of 32,000 lb. or 53,000 lb. per sq. in.

It will be noticed that just before rupture occurred the increase in length was 2 in. and, since the sample originally was 8 in. long, the elongation in 8 in. was 25 per cent. Test samples of round stock are made ordinarily only 2 in. long; data on test samples are given in the S. A. E. Handbook.[3]

The diameter of the sample is 0.572 in. at the place of rupture, or 0.257 sq. in.; hence the reduction in area is $(0.6013 - 0.257) \div 0.6013 = 57$ per cent approximately.

Full details of the test for the modulus of elasticity are given in Chapter XVII of my textbook on Motor Vehicle Engineering, but this test is not sufficiently accurate to show the exact deformation or elongation, within the elastic limit of the material; but we can estimate it to be about 0.01000 in., or 0.00125 per in. of length, when the load is 20,000 or 33,200 lb. per sq. in. Therefore the modulus of elasticity, E, is as follows:

$$E = \text{Stress/Strain} = 33{,}200/0.00125 = 26{,}500{,}000 \text{ lb. per sq. in.}$$

THE DISCUSSION

Adrian Van Muffling: What is considered the usual factor of safety?

[3] See S. A. E. Handbook, vol. 1, p. D4.

E. FAVARY: There is a great variation in the factor of safety. My idea of a satisfactory factor is to take double the load, take into consideration all the stresses for this load and then allow a factor of safety of five. I advise considering double the load because I figure that the springs can be deflected only to about double their normal static deflection. Of course, this does not always hold good, but I have assumed this as the maximum load. If the frame is either too rigid or if too flexible, it is not satisfactory. Frames now are made more rigid than formerly.

C. M. BILLINGS: Is not most of the breakage resulting from the stresses imposed due to the frame being supported on four rather than three points? It seems wrong in principle to subject the frame to stresses caused by inequalities of the roads. Would not a three-point suspension such as is used on tractors be better?

Mr. FAVARY: A frame gives and if there is an excessive strain in a certain part of it or if the frame is longer, it will cause a greater bending moment and a greater fiber stress in the channel. I cannot see how three-point suspension can reduce the fiber stress due to a given load.

Mr. BILLINGS: In the case of an ordinary four-wheel truck, with a heavy load on its platform, the side-rail member is subjected to torsion as well as the bending stress due to the superimposed load. It is weaker than when subjected to the ordinary bending load?

Mr. FAVARY: Yes, but I question whether this torsion is sufficient to be of importance, for a very small torsion in one side-member will permit the other to rise considerably. Do not forget that there is some play in the spring-shackles. We know very well that we can take a piece of frame channel and twist it somewhat without damaging it. I think it is very rare for frames to give way as a result of torsion.

Mr. BILLINGS: One of our reasons for concluding that frame distortion causes much trouble is the vertical displacement of the rear doors of a motor-truck body. This up-and-down motion is particularly noticeable on a large van body. It has always been a problem to keep the bolts tight on the chassis and the body.

Mr. FAVARY: No doubt the frame does distort and a more rigid frame distorts the body less but I do not believe the ordinary distortion exceeds the elastic limit of the metal. A piece of channel iron can be twisted considerably.

Mr. BILLINGS: Not indefinitely.

N. G. BERGENHOLTZ: That is in the case of a rigid frame. I agree that there would be a large amount of stress due to the four-point-suspension semi-flexible frame. I have found that if one wheel is raised 10 in. above the ground, which is a fairly good height, the side-member does not twist over 1/16 in. I think the stress affects the cross-members more than the side-rail, because they seem to be twisted more. There does not seem to be any distortion in the side-member.

Mr. DEAN: Does not the stress have a tendency to loosen the rivets?

Mr. FAVARY: No.

FRAME RIGIDITY

Mr. DEAN: Does not the twisting of the frame wear the shackle-pins and bushings?

Mr. FAVARY: Yes, perhaps, but it seems more desirable to take the wear on them than on some of the other units.

Mr. DEAN: Can it not be eliminated by making the frame absolutely rigid?

Mr. FAVARY: There is no such thing as absolute rigidity in mechanics.

Mr. DEAN: I mean as nearly rigid as is possible. When an engine is carried in the frame without any subframe, are we not liable to distort the engine-base?

Mr. FAVARY: We often rely in such cases on the engine-base for added rigidity. At other times builders provide a certain swivel action to permit the engine to adapt itself to the frame when there are slight distortions.

Mr. DEAN: The Pierce-Arrow truck has a flexible frame; do you think there is any wear on the shackle-pins?

Mr. FAVARY: Yes.

Mr. DEAN: Is it due to the twisting of the frame?

Mr. FAVARY: I am not prepared to say. We learn in the laboratory that one conclusion is not final; when we think we have solved a problem or that we know the reason of some new effect we make confirmatory tests. We must suspend judgment until the circumstantial testimony is such that it can be relied upon. We should never judge finally by one or two cases.

Mr. DEAN: Is it not a fact that, due to the twisting of the frame, the spring-clips become loose?

Mr. FAVARY: In a measure probably.

Mr. DEAN: Why not adopt a more rigid frame on the order of the three-point suspension and eliminate that difficulty? Would there not be less wear on all parts?

Mr. FAVARY: Practice has shown that where too rigid a frame is used breakages often occur which do not take place in a more flexible frame. In case of impact the stresses are very much more severe in a relatively rigid body.

Mr. DEAN: Why not make the spring suspension flexible instead of the frame itself?

Mr. FAVARY: A number of different devices have been tried to obtain this result but it would be presumptuous on my part to answer the question offhand.

Mr. DEAN: In a long experience I have found that the spring-clips become decidedly loose on all makes of truck; but on the Pierce-Arrow the spring-clips and the shackle-pins very seldom become loose. The flexible frame distorts the body and it is impossible to keep it tight. Why distort the body to make the frame flexible, and still have a flexible suspension?

Mr. BERGENHOLTZ: I think that there is more wear on the pins with a rigid frame. With the flexible frame the springs are not distorted so much in going over obstructions. Regarding the distortion of the semi-flexible frame, another thing is that there is a long lever-arm up to the front end of the truck and, if one of the front wheels is raised about 10 in., it will be found that one side of the frame rises only about 2½ in. above the other. In other words, the spring action absorbs much of the up-and-down movement of the wheels and, because the frame is flexible, it tends to keep the springs more in line and eliminates the side-weave. Another point is that the springs must be rigidly fastened to the axle in the present form of construction, which is practically universal, to take care of any side-movement. If the spring were flexibly mounted on the axle, there would be nothing to prevent the side-movement of the whole frame. We can use a rigid frame and save the body at the expense of the frame, or a flexible frame, which will last longer, and put a new body on it from time to time.

W. C. GREENE: Let us take a sane view of the matter of torsional stress, since that stress is distributed over rather wide limits. If we were dealing in short distances, we would have something to worry about, but we

have very little actual bending-moment per unit of length.

Engine Mounting in the Frame

D. Landau: The Mercedes has a four-point suspension crankcase and depends on that to keep the frame side-members the proper distance apart. With too flexible or too rigid frames the strain on the mechanism is of considerable importance, so far as the frame is concerned; that is, if the frame is distorted, there is a tendency to jam the units of the mechanism.

Mr. Bergenholtz: This is a more important point, I think, than the distortion of the frame. We have a three-point engine suspension. The front point is rigidly fastened, as regards sidewise movement in the frame, and the two rear supports are rigidly fastened. We have a triangle that does not allow much flexibility so far as movement of the side-members is concerned.

I understand that there have been a considerable number of breakages lately of flywheel housing arms, at the point where they are supported. I suppose that this is due to their being too light. With a flexible frame a flexible rear engine-support is necessary, or the crankcase must be stiffened to take care of the strain imposed by the distortion of the frame. I think we must work with the flexibility of the units, to keep the frame flexible or semi-flexible.

Joseph A. Anglada: In the past few years we have been gradually increasing the depth of the frames; last year this was done very decidedly. A number of car builders have increased the depth to 6, 8 and 8½ in. They are using better material, and are making the frames rigid. There was an idea that the flexible frame has the advantage of making the car ride more easily. It does not. We have better riding cars now with the stiff frames than we had with the flexible frames, because we know how to make better springs. In addition, when we make a body and put it on the frame, there is no difficulty about opening the doors. As to the factor of safety, I had occasion to make investigations of broken frames and, in each case where a frame was broken, I found that the factor of safety was less than 10, with a static load.

Mr. Billings: In the development of a three-point-suspension truck and in figuring the stresses on the majority of the well-known trucks, we have found that they were pretty well up to the safety limit according to the way we analyzed them, which we believe was the correct way. The frame on the three-point-suspension truck was made of 8-in. standard I-beams, and was perfectly rigid. There were no spring-shackles, so there was no trouble with shackle wear.

Mr. Favary: When a frame is made as heavy as that, do you not carry too much dead-weight all the time?

Mr. Billings: The weight of the chassis complete, with gasoline, oil and water, is 8130 lb. We have repeatedly obtained an average of 6 miles per gal. of gasoline.

W. A. McKinley:—The method of computing stresses for an automobile is very simple after certain assumptions and allowances are made. An overload of 50 per cent is generally allowed in the case of truck frames, the load being considered as distributed equally over the platform. Assuming a tensile-strength of 60,000 lb. for steel and a factor of safety of 10, the stresses can be computed either algebraically or by the string polygon method, the former being the more accurate. It must be assumed first that the side is a beam supported at two points; this assumption is not exact, but it approximates the actual condition closely enough to be used.

The first step after laying out a proposed frame is to plot the bending-moments at intervals of the frame length, together with the moment of resistance. This will show immediately where the proposed frame is weakest and where the sections must be increased. Obviously, it will show also where the frame can be lightened considerably. This information, together with considerations affecting economical manufacture, will enable the designer to distribute the metal properly along the rail so that no excess dead-weight will be carried by the chassis. There seems to be a wide diversity of opinion as to how heavy truck frames should be made. I heartily endorse Mr. Favary's view as to the need for a greater amount of standardization data for truck frames.

Stiffness is a quality that engineers demand increasingly. We have seen the general trend of design change from 3½ and 4-in. section rails to 7 and 8-in. rails on present-day construction. This was done not only to increase the strength or the resisting moment, but also to increase the stiffness. Whatever arguments are advanced for flexible frames, it must be remembered that other more important units are subjected to severe strains when a frame is allowed to flex. For this reason alloy steels are not in wider favor. Although it is very easy to design an alloy steel section that is smaller in size and of lighter stock and to obtain the same resisting moment as when the larger carbon-steel section is used, the stiffness of the section is proportional to the modulus of elasticity of the material and this is the same for both carbon and alloy steels. Consequently, lightening the section means a sacrifice in stiffness, a fact which cannot be ignored.

C. L. Clark:—The frame is an important unit in truck and automobile construction, and yet it is the least standardized. As Mr. Favary says, there is a wide difference in the stress in the frame side-members of trucks of various makes. This indicates either that the manufacturer has not accepted a certain factor of safety as standard, or that the stresses have not been checked. The same condition exists among automobile builders. The result is that trouble with breakage has occurred. Often, the first thought of the engineer is that the material is at fault; yet in the majority of instances a careful analysis of stresses indicates a weakness in design. On the other hand, many truck frames are too heavy and a saving could be effected in both material and weight.

It is important in designing a frame to prepare a loading diagram from which the bending-moment diagram or curve can be drawn and the static stresses determined throughout the length of the side-member. It is not sufficient to consider the frame as being satisfactory after this investigation, because failure may develop on account of the use of an insufficient number of cross-members, lack of bracing to hold the frame square, or an improper mounting of units.

Several types of truck frame are in use. The side-members are straight and of uniform depth, tapered at one or both ends, or formed with a nose-bend at the front end for the front spring-horn. An offset is used frequently for the light and medium-weight trucks; it is located somewhat to the rear of the front wheel to provide a shorter turning-radius. The flanges are tapered usually, although the practice in this respect is not uniform. Reference to Mr. Favary's bending-moment diagram indicates the feasibility of tapering both the front and the rear ends of the frame side-member. It also discloses that the center section, that is, the section of the side-member between the front-spring rear-bracket

and the rear-spring front-bracket, serves as a convenient basis for checking the suitability of a frame for a truck. For a given truck, assuming that a section modulus for the section at the point of maximum moment is 4.5, then for another truck having nearly the same loading diagram and wheelbase an approximately equivalent section would be required. We are thus enabled to adopt certain standard values for the section modulus of side-members for trucks of different capacity, making proper allowance for vibrations in wheelbase and distribution of load. This information is of considerable value as a guide in determining the suitability of a frame for a truck of known capacity.

In general, the same factors relating to the strength of truck frames apply to automobile frames; however, more careful consideration is given to weight. The tendency is to make the center section of the side-member relatively more rigid, on account of the effect of deflection upon the body. For spring-brackets, experience points to the desirability of keeping shackle-pins below the lower flange of the rail when possible; otherwise a deeper rail-section must be used at the shackle. In any event the strength of the side-rail member must be checked carefully at these points, because frame breakage will develop if a sufficient factor of safety is not maintained. Another possible source of trouble lies in the mounting at the rear engine-supports. Some car-builders prefer to carry the rear end of the engine on brackets projecting out from the side-members. This mounting, unless of such design as to comprise in effect a rigid cross-member, sets up a torsional stress in the side-member, in addition to the vertical load due to the weight of the unit supported. The torsional load is augmented very considerably by road shocks and requires the use of a stronger side-member than would be necessary with the rigid-cross-member type of support. I have traced the failure of a number of frames to the method of mounting at the rear engine-supports.

Too much stress cannot be placed on the fact that, to avoid breakage, the engineer should make sure that there are no weak points in the frame design. Having determined this, he is then in a position to increase the strength of the members if greater rigidity is desired. This procedure will discount to a considerable extent the development of possible weakness in frames after the cars have been subjected to use.

ENGINEERING SUCCESS

THE most important elements that contribute to the success of an engineer can be included under five heads: (*a*) technical ability, (*b*) breadth of knowledge, (*c*) initiative, (*d*) executive ability and (*e*) ability to write and speak clearly and forcefully. Apparently, in the past at least, the chief aim of the engineer has been to perfect himself in technical details. Many, if not most, engineering instructors have been impressed with the magnitude of the field of engineering knowledge and have given their best effort to imparting to their students what they believed to be the technical information needed in their future work. Therefore, the chief aim of the engineering student has been naturally, and almost universally, to acquire facts about his chosen profession. The mere accumulation of technical information has little or no educational value. The power to observe closely, reason correctly and make clear statements is of vastly greater importance than any amount of technical information; technical details without these qualities are absolutely useless. Technical details speedily get out of date; but these qualities are never out of date, and are always valuable whatever a man does.

The student should seek continually to get the maximum intellectual development as he acquires technical facts. He should seek to understand the relations between the facts and fundamental principles. Inquire the reasons for the particular practice and determine whether it is general or due to some limiting condition of time or cost. He should regard his study as a test of how quickly and certainly he can acquire the significant facts from the printed page. The development of the mental powers alone confers that which masters all it touches, can adapt old forms to new uses or create new and better means of reaching old ends; and without this power the engineer cannot hope to practice his chosen profession for any very great length of time with any considerable chance of success.

The engineer should understand at least some of the fundamentals of economic problems, social conditions, political questions, legislative action and know something of the subtle relations of labor and capital, the factors affecting international trade and other questions that form the subject of the thought and the conversation of his business associates and other professional men. If the engineer is found seriously lacking in knowledge of these subjects, the layman considers him an ignorant man.

Without the power of initiative, the power of self-direction, no one can hope to be trusted with much responsibility. Men who are at the head of large enterprises and carry great responsibilities are always looking for those who have initiative; and not infrequently they choose the uneducated man, or perhaps I should say the unschooled man who has the power of initiative, in preference to the college-trained man who does not have it.

A good executive is a man of initiative and self-reliance, who understands other men and knows how to secure their hearty cooperation. This requires tact, patience, perseverance, courage, ability to judge men, knowledge of character and understanding of motives. The engineer does not usually give heed to these matters, this is at least one reason why he is seldom advanced to the higher administrative positions. Administrative officials are always looking for men who will help them to carry their load, and invariably the pay is comparatively high because such men are relatively scarce. Many high-priced positions in the engineering field are held by non-engineers because no engineer could be found with the necessary executive ability.

The engineer, in college, and also after graduation, has been so intent upon perfecting himself in technical details that he has neglected the means of communicating his thoughts by writing or speaking to his fellow men. The engineer, if he is to attain to any considerable prominence or influence in his community, must do business with other men, explain plans, write letters, prepare contracts, give testimony in court and write reports; unless he has acquired the ability to express his thoughts in clear and forceful English he cannot influence others to accept his views or convince them that he is an intelligent or educated man. Other men are not able to judge him by his technical attainments, but do judge him by his ability in writing and speaking. Unless he uses clear and forceful language, others are likely to assume that he is an ignorant man, and consequently his professional standing suffers and his influence as a citizen is weakened.—From an address by I. O. Baker before the Purdue University Student Chapter of the American Society of Civil Engineers.

Anti-Freezing Solutions

IN connection with the Farm Power Session of the Society held at Columbus, Ohio, Feb. 10, 1921, a preliminary report of the Committee on Anti-Freezing Solutions was made by O. B. Zimmerman, of the engineering staff of the International Harvester Co., Chicago. The report as presented is given below.

Preliminary Report

This Committee presents a report of progress at this time on the status of anti-freezing solutions, which is of recurring interest yearly. Relatively little constructive work has been done on this question other than that of designing a cooling system to operate with water as the cooling medium. The function of the cooling system is that of taking care of a quantity of heat units liberated by combustion greater on the average than is transformed into mechanical power and nearly equal to that ejected with the exhaust. It seems worth while, therefore, to give a more detailed study to the question of the media possible of use.

Satisfactory lubrication of pistons, piston-rings and valves is dependent very largely upon the successful removal of approximately 30 per cent of the heat units from the gasoline and kerosene fuels used and dissipated during the working cycle of today. Again, in the necessity of having to meet a wide range of normal seasonable temperatures, as well as extremes of winter and summer, we find that we have a real research problem to solve. Even before the development of internal-combustion engines efforts were made to overcome the deficiencies of water as a cooling medium, but with the coming into use of internal-combustion engines the evil or aggravating results produced by the sedimentary deposition of soluble substances, as well as those mechanically carried into the cooling system by land waters, have caused much trouble, especially in farm tractors, the water supplied to which is too often carelessly or of necessity poorly chosen and in which the deposition is more extensive than in automobiles. This is owing to the higher average temperature, and the accompanying danger of overheating in spots even when large free passages are provided and no blind pockets are present. Expensive repairs due to jacket freezing, radiator leaks, frozen pumps and the like excited a series of attempts to solve this difficulty by mechanical means. Examples are found in air-cooling, mechanical devices to prevent damage by expanding ice, devices of various kinds to control low temperatures by the use of heat and devices providing for the automatic withdrawal into storage of the fluid when the engine is inoperative. Also there have been numerous efforts to solve the problem by the use of mixtures of salts or other chemicals in solution with water to lower the freezing-point of the mixture; such examples as calcium chloride, common salt, glycerine, alcohol and glycols can be mentioned. Lastly, there is the series of mineral oils that maintain fluidity or resist both high and low temperatures within the reasonable demands of out-of-doors engine practice. It is the endeavor of the Committee to review these last two groups with the idea that whatever the final conclusions may be, the state of the art should be defined. Further detailed study and research can then be undertaken in the same thorough manner as that in which the subjects of lubricants and fuels are treated.

That the precautions against freezing occasion the greatest amount of anxiety in winter and result in the largest percentage of damage to the machine if not closely guarded against, is freely acknowledged; hence, it is our duty to overcome this difficulty. Taking the ideal requirements of a cooling medium as a basis to work from, we can enumerate these requirements briefly as follows:

(1) The cooling medium must be cheap and easily obtainable
(2) It must be reasonably non-corrosive, and not cause electrolytic action
(3) It should have a boiling-point not too high above that of water, such as 250 deg. fahr.; it should not freeze much above minus 20 deg. cent. (— 4 deg. fahr.) or about zero fahr.
(4) It must be a mobile fluid or have a low viscosity through this range
(5) The fire hazard should be at a minimum
(6) The specific heat should be as nearly that of water as is practicable, and the heat conductivity should be as high as possible
(7) Low expansibility is desirable
(8) It must withstand the continuous heat of an engine without undue decomposition or molecular change
(9) If practicable, it should be a year-around fluid or one that is readily capable of replacing water in the winter months
(10) It seems feasible to consider groups of requirements to fit not only needs but also personal factors, where expense and care do not control, as compared to tractor requirements

With these requirements in mind we shall scan the information furnished by a review of patent office data, supplemented by the experience of different operators and firms. A review of the subject of anti-freeze solutions has already appeared in THE JOURNAL,[1] this being a preliminary statement of the Bureau of Standards, which is investigating the subject. Since that article had in view, primarily, the requirements of automobiles and the report of this Committee covers trucks and tractors as well, a duplication of certain conclusions and data is warranted.

It must be acknowledged freely that the use of salts like calcium chloride, in the hope that the average user would make his own solution, is out of the question; the average user's knowledge of the purity of substances being exceedingly meager, it seems sensible to leave his choice of solutions along this line open only to the selection of such reliable articles as may be available. The consensus of opinion is, however, that this method of using salts for preventing freezing is dangerous and undesirable, because electrolytic action is almost certain to follow; and that it should be discouraged at present.

In the use of alcohols we undoubtedly find almost a unanimous opinion in favor of this method of reducing freezing difficulties, although the free boiling-off of the alcohol leaves constant uncertainty as to the nature of the solution and its cold-resisting qualities. The tables formerly given in the S.A.E. HANDBOOK are satisfactory, but it appears desirable to add thereto the tables given by the Bureau of Standards in its preliminary report covering the use of alcohols and glycerine. Pure amyl alco-

[1] See THE JOURNAL, October, 1918, p. 285.

hol, in addition to methyl and ethyl alcohol, has had a thorough trial and is in a fair way to be recommended. This alcohol is a variety of amyl hydrate obtained by the fermentation of potatoes, and should be produced cheaply and easily. The mixture of 1 part of amyl alcohol with 39 parts of water forms a liquid of 0.998 specific gravity. This liquid freezes at —20 deg. fahr. and has a boiling-point of 264 deg. fahr.; hence, unlike ethyl and methyl alcohol, it has the advantage of not boiling off ahead of the water. Its specific heat is given as 1.6.

In the review of patents we find one covering the use of glycols of the 1.2 type, which in approximate proportions of 60 to 65 per cent of water and 40 to 35 per cent of glycols, make a very satisfactory cooling medium. A good discussion of this subject is given in United States Patent No. 1,213,368. Other United States patents to review are Nos. 1,102,777, 1,082,528, 1,282,249 and 1,319,178.

There remains to discuss the group of mineral oils and their use as a cooling anti-freezing fluid. Numerous opinions have been given against the use of oils but in each case, so far as we are aware, the opinion has been based on guesswork rather than experience. The fact remains that, in the development of heavy tractors from 1904 to date, successful cooling has been accomplished and persists with the use of heavy oils covering all seasons of the year. The Committee has numerous records of trucks and several makes of automobile having used kerosene without difficulty throughout the winter season. While the heavy oils require certain special design features to accomplish complete success, on the whole the difficulties noted are not serious. Technical data covering the characteristics of these mineral oils for this purpose are not at hand and efforts are being made to secure them for the final report. Such information as relates to heat conductivity and specific heats, speed of heat transfer from medium to metal and metal to air, and the like will require more research. The rates of diffusion and absorption have not been obtained. The difficulties reported or noted when using kerosene cover the following:

Leakage The pumps normally require better care than with water to minimize the danger from fire and undesirable odors

Destruction of Hose The life of hose is reported to be from three months to two years according to quality. This is a minor expense compared with the convenience, in the opinon of several who have used kerosene

Odors For use in the better quality of cars, this feature is worthy of consideration. With tractors and trucks, odor is not so important a determining factor

Foaming The presence of water in the system along with the oil is very undesirable; hence, careful draining is an important preliminary to replacement with oil. Usually, operators report little trouble after the first elimination

Short-Circuiting This difficulty seems noticeable at the start when the outfit is still cold, because of congealing when the heavy oils are used in extremely cold weather. This difficulty is overcome readily by the addition of a small percentage of kerosene

Expansion Provision must be made for the greater expansion of oil with heat; when oil is substituted for water

Viscosity Free or larger passages are more necessary than with water

Low Specific Heat This runs about one-half that of water; hence the necessity of giving more speed to the circulation

Fire Hazard An increase in the fire hazard has been reported by a number of representatives, but so far no record is at hand as to actual destruction from this cause

The general conclusions at this time are that the subject deserves special and more complete study, particularly from the standpoint of the truck and the tractor, as these machines are subjected more completely to intense heat and cold and must be ready to do their duty at all times.

The preliminary report on this subject of the Bureau of Standards, dated Jan. 5, 1920, is appended.

Report of the Bureau of Standards

The question of anti-freezing solutions for automobile radiators has been brought very forcefully to the attention of users of motor vehicles this winter, and many requests for information regarding their use have been received at the Bureau of Standards. An investigation was undertaken by the Bureau to establish the value of these compounds and sufficient data have been obtained recently to justify a preliminary statement. The tests were made on the metals, such as brass or copper and solder, that are used in radiator construction and in the same combinations that are employed for this purpose. This was necessary to investigate the electrolytic action that is largely responsible for radiator corrosion; tests made without regard to electrolysis are practically worthless. This work will be continued; tests equivalent to service conditions will be made and a more comprehensive report given at a later date.

The ideal anti-freezing compound is one that will prevent freezing of the radiator liquid without injuring either the engine or the radiator, that will not lose its non-freezing properties after continued use and that does not change materially the boiling-point of water when dissolved in it. There are two general types of these compounds; one a solution in water of alcohol or glycerine, or a mixture of the latter two, the other a solution in water of calcium chloride or the dry salt itself that sometimes contains small amounts of other substances such as salt, sal ammoniac, sugar or syrup. Kerosene and similar oils, without admixture, are sometimes used. Kerosene has a lower freezing-point and a higher boiling-point than water, but the inflammability of its vapor makes it dangerous to use, and its high and uncertain boiling-point might lead to the serious overheating of the engine, or even to the melting of the solder in the radiator. It has a marked solvent action on rubber parts. These facts seem to indicate clearly that this material should not be used. The alcohol-water type is the most common and is not generally sold under any trade name, but recently there have appeared on the market a number of anti-freezing compounds of the calcium-chloride type. These compounds are sold under a variety of names and startling claims are made for their effectiveness and lack of injurious effects. The effectiveness of all properly prepared compounds, that is, their ability to prevent freezing, needs no discussion. The injurious effects, however, cannot safely be disregarded.

The alcohol solutions do not exert a greater corrosive action than water alone. This can be predicted from theoretical considerations and is well established in practice. However, wood alcohol sometimes contains free acetic acid, which is objectionable. For this reason, wool alcohol should not be used unless it is known to be free from acid. The calcium-chloride compounds exert a greater corrosive action than water on the engine jacket, on the

solder in the radiator and on the aluminum that is sometimes used in manifolds, pumps and headers. The effect on engine jackets can be neglected since these are generally sufficiently heavy to permit considerable corrosion without their being weakened. The effect on soldered joints may be serious, since tests made at the Bureau of Standards have shown the complete removal of solder from copper and brass when immersed in a hot 20-per cent calcium-chloride solution for 4 days. A number of such tests were made and there was always a more rapid corrosion or eating away of solder in these anti-freezing compounds than in water. Calcium-chloride solutions corrode aluminum very rapidly. The effect is variable, depending on the kind of aluminum used; blisters appear on ordinary rolled sheet-aluminum and, as these break, the metal separates into scales or plates of corroded aluminum that open up like the leaves of a book; cast aluminum, especially the copper alloys, shows very decided pitting and etching. These tests prove that the corrosive action will be very serious and it is difficult to reconcile these results with the current statement that the effect of calcium-chloride solutions on aluminum is not very serious. Another troublesome effect of calcium-chloride solutions is experienced if small leaks occur in the radiator, the water-jackets or their connections, and the solution comes in contact with the spark-plugs and ignition wires. In some cases the drops of the solution may be carried back on the engine in a more or less atomized state, assisted by the fan when running. The salt deposited when the water evaporates is very difficult to remove and, when it cools, it absorbs water and becomes a good electrical conductor, short-circuiting the spark-plugs and sometimes making it impossible to start the engine. The difficulty may disappear when the engine is heated up. There are also certain conditions in the manufacture of calcium chloride that may result in a compound that will deposit large crystals in the radiator as the solution cools; this may prevent effective circulation.

Regardless of these objections, reports have been received to the effect that calcium-chloride solutions have been used a number of years in the same radiator without producing apparent corrosion. Nevertheless, such solutions cannot be recommended as safe, and they should not be used if there is any aluminum in the cooling system. The chief advantage of calcium-chloride compounds is that they are not volatile. The solutions can be kept practically uniform by adding water from time to time. Unfortunately, this is not true with the alcohol solutions, because the alcohol continually boils out and must be replaced frequently to maintain the proper proportion of alcohol. Glycerine is frequently substituted for part of the alcohol to reduce evaporation, but when glycerine is used the rubber connections may be affected somewhat seriously, depending on the quality of the rubber. The most practical method to maintain the proper quantity of alcohol in the solution is to determine the specific gravity of the liquid with an hydrometer and, by reference to Table 1, add the necessary quantity of alcohol to obtain the desired specific gravity. Care should be taken to have the solution thoroughly mixed and, as the specific gravities given in the table are obtained at 60 deg. fahr., the specific gravity should be measured when the temperature of the solution is between 55 and 65 deg. fahr. The solution can then be kept at the proper strength from day to day by adding alcohol until the hydrometer reads the same as when first noted.

To illustrate how a non-freezing solution is prepared by using Table 1, assume that the lowest temperature anticipated is 19 deg. above zero fahr. and that denatured alcohol is to be used. By reference to Table 1, in the line marked Denatured Alcohol, plus 19 deg. fahr. is found in the 20 per cent column and the specific gravity of that solution is 0.978. If the radiator holds 3.5 gal., 20 per cent of this must be alcohol and the remaining 80 per cent water. Twenty per cent of 3.5 gal is 0.7 gal. or a little more than 5.5 pints which is the quantity required. This should be added to enough water to make 3.5 gal.; that is, the water used will be 3.5 gal. less 0.7 gal. or 2.8 gal., a little more than 11 quarts. If the temperature of this solution is brought to 60 deg. fahr. and an accurate hydrometer is floated in it, the hydrometer should read 0.978. If the reading is higher than 0.978 more alcohol should be added with constant stirring until the 0.978 mark is reached. An accurate hydrometer should read 1.000 when placed in water at 60 deg. fahr. and 0.834 in 180-deg.-proof alcohol at the same temperature. The denatured alcohol usually sold by dealers is 180-deg. proof, which is the minimum allowed

TABLE 1—FREEZING-POINTS AND SPECIFIC GRAVITIES OF THE BUREAU OF STANDARDS ALCOHOL AND GLYCERINE ANTI-FREEZING SOLUTIONS

	Denatured Alcohol	Wood Alcohol	Glycerine	Denatured Alcohol and Glycerine[2]	Wood Alcohol and Glycerine[2]
10-Per Cent Solution[1]					
Freezing-Point, deg. cent.	−3	−5	−2	−4	−4
deg. fahr.	+27	+23	+29	+25	+25
Specific Gravity at 60 deg. fahr.	0.9880	0.9870	1.2537	———	———
20-Per Cent Solution					
Freezing-Point, deg. cent.	−7	−12	−6	−8	−9
deg. fahr.	+19	+10	+21	+18	+16
Specific Gravity at 60 deg. fahr.	0.9780	0.9750	1.2537	———	———
30-Per Cent Solution					
Freezing-Point, deg. cent.	−12	−19	−11	−13	−15
deg. fahr.	+10	−2	+12	+9	+5
Specific Gravity at 60 deg. fahr.	0.9680	0.9630	1.2537	———	———
40-Per Cent Solution					
Freezing-Point, deg. cent.	−19	−29	−18	−22	−24
deg. fahr.	−2	−20	0	−8	−11
Specific Gravity at 60 deg. fahr.	0.9570	0.9520	1.2537	———	———
50-Per Cent Solution					
Freezing-Point, deg. cent.	−28	−40	−26	−32	−35
deg. fahr.	−18	−40	−15	−26	−31
Specific Gravity at 60 deg. fahr.	0.9430	0.9370	1.2537	———	———

[1] Glycerine and alcohol are mixed in equal proportions; a 10-per cent solution of glycerine and alcohol, for instance, means that 5 parts of glycerine and 5 parts of alcohol should be added to 90 parts of water.

[2] Percentage, by volume, in water.

by law. A solution so prepared will not begin to freeze until its temperature is approximately plus 19 deg. fahr.

A careful consideration of the question of anti-freezing solutions for radiators leads to the conclusions that

(1) Calcium-chloride compounds should be used with caution, if at all, on account of their corrosive action
(2) Kerosene or similar oils should not be used on account of their inflammability, high boiling-point and effect on rubber
(3) Mixtures of glycerine and alcohol can be used, but the price of glycerine may preclude its use
(4) Solutions made from either wood or denatured alcohol seem at present to be the most desirable anti-freezing solutions to use. If the wood alcohol is free from acid there is little choice between the two. Wood alcohol costs more and is more volatile, but its lower freezing-point allows a less amount to be used, which may counteract the above disadvantage

Numerous tables have been published giving the freezing-points of certain water solutions containing alcohol, glycerine or a mixture of the two, but there is much disagreement in the figures. Table 1 gives freezing-points obtained from actual measurements made at the Bureau of Standards on solutions of commercial materials; it can be considered sufficiently accurate for practical purposes, since the freezing-points agree fairly well with the most reliable scientific data.

The freezing-point is taken to be that temperature in the cooling process at which crystals begin to form. The temperature at which the entire mass becomes solid may be several degrees lower than the freezing-point for dilute solutions, and 10 to 15 deg. lower for the more concentrated solutions. As an example, a 30-per cent solution of denatured alcohol begins to freeze at 7 deg. fahr., that is, small crystals of ice form, but the solution does not freeze solid until a temperature of 5 deg. below zero, or lower, is reached. Hence, a temperature considerably lower than that given in Table 1 for any given percentage of alcohol would not injure the engine or radiator. However, it seems desirable to keep the solution at such a concentration that ice crystals will not form at the lowest temperature to be encountered, since they may interfere with the circulation.

Method of Reading Hydrometer

The solution is placed in a clear glass jar or cylinder and the hydrometer carefully immersed in it to a point slightly below that to which it naturally sinks; it is then allowed to float freely. In taking the reading the eye should be placed slightly below the plane of the surface of the liquid and then raised slowly until this surface, seen as an ellipse, becomes a straight line. The point at which this line cuts the hydrometer scale should be taken as the reading of the instrument.

THE DISCUSSION

J. A. Secor:—I fully agree with all the conclusions Mr. Zimmerman reported except those relating to alcohol, regarding which I have no personal knowledge. I will present the following notes on oil-cooling.

Oil-Cooling

Oil-cooling of tractor engines has the advantage of adaptability to all climatic conditions and all atmospheric temperatures. In the past 11 years approximately 30,000 Oil-Pull tractors have been equipped with oil-cooling systems. There have been no complaints from the field relating to oil-cooling. Not more than two or three cases have been reported where water was used by the tractor owner in preference to oil, and these few exceptions were in tropical countries. The oil-cooling system is simple, requires little attention in the field and is almost foolproof. No time is lost in refilling the radiator in summer, or in draining and refilling in freezing weather, or in replacing broken belts. Power is not used for operating the fan. In place of the fan, the air for cooling the radiator is drawn through it by the inductive effect of the exhaust discharged from nozzles located in a hood placed over the radiator. The circulation of cooling oil from radiator to cylinder and return is made positive by a centrifugal pump of ample capacity driven by spur gears from the camshaft of the engine.

The tractor tests made in 1920 at Lincoln, Neb., by the State University, demonstrate that even in summer oil-cooling has incidental advantages. Sixty-five tractors were tested between April and October inclusive. In many respects these reports are conceded to "represent the greatest fund of tractor information available. The results may be taken as representative of average performance." The test reports show that on 23 occasions repairs were made to the fans or belts of 17 different tractors. Delays and expense from this source are eliminated throughout the entire life of an Oil-Pull tractor.

In the oil-cooling system there are no parts requiring readjustment or repair with the exception of an occasional replacement of the packing in the pump-gland; usually, about once in each season. The oil for cooling should be non-freezing, free from moisture, and have an initial boiling temperature above 500 deg. fahr. Zero Black, Winter Black, Gargoyle Arctic Oil C and Gargoyle Teleo Oil are trade names for such oils. Ordinary commercial Winter Black is commonly used. Owing to the differences between oil and water in respect to viscosity and heat conductivity, radiators designed for water-cooling are not usually suitable for oil-cooling. The Oil-Pull tractor has about 8 sq. ft. of cooling surface per rated brake-horsepower of the tractor, and ½-gal. volumetric capacity per brake-horsepower for filling jackets, connecting pipes and radiator.

There are numerous instances of motor vehicles in which kerosene has been successfully substituted for water for winter use, but the data as yet are insufficient to warrant any general conclusions regarding the feasibility of oil-cooling for automobiles. Kerosene has an average initial boiling-point of approximately 300 deg. fahr., whereas the initial boiling-point of the Winter Black oil used in tractors is from 550 to 575 deg. fahr. The general characteristics of Winter Black Oil are given in Table 2.

TABLE 2—CHARACTERISTICS OF WINTER BLACK OIL

Pour-Test, deg. fahr.	20
Viscosity at 104 Deg. Fahr., sec.	181
Viscosity at 210 Deg. Fahr., sec.	46½
Flash Test., deg. fahr.	345
Fire Test, deg. fahr.	385
Initial Boiling-Point, deg. fahr.	550
End-Point, deg. fahr.	750

The viscosity diminishes very rapidly as the temperature of Winter Black oil increases. Due to its relative viscosity at freezing temperatures, it is customary to add kerosene to Winter Black, thereby reducing its viscosity so that it can be pumped freely. As the weather becomes warmer, the kerosene appears to evaporate gradually and can be replaced with undiluted oil. Gargoyle Teleo Oil, however, has the advantage of the extremely low pour-test of 20 deg. fahr. The average temperatures of cool-

ing oil when discharged from the cylinder jackets lie between 150 and 225 deg. fahr., according to the model, load and speed of the engine. Its maximum operating temperature is always more than 100 deg. lower than its flash-point. Winter Black does not crack or deposit tarry material at its working temperatures. In fact, after 11 years of use in our early tractors, no cases have been reported where the interiors of the radiator or the jackets have been clogged by scale or deposits of any kind. However, only a suitable oil of known characteristics should be used for cooling.

A MEMBER:—There is no danger to the solder of the radiators at 225 deg. fahr. I think that ordinary radiators could be used for oil-cooling, except that the water passages would have to be made larger.

MR. SECOR:—The water passages are too small for oil, and the radiator capacity would have to be greater. Tubular radiators of sufficient capacity can be used for oil-cooling.

D. R. HARPER:—The foregoing remarks have suggested to me that there are two possible lines of improvement. One is to ascertain whether an anti-freeze solution can be found for use in the radiators already developed; and the other is to consider just what changes might be required in the radiator to make it better adapted to the most convenient fluid, whether that be water or another fluid that might give a wider range of use with equal convenience. I think there is no doubt in the minds of most of us that the latter is the course that will be followed. If there are liquids other than water that will be serviceable, every effort will be made to have the radiators designed so as to use them equally as well as water is used now. I suppose it was with that thought in mind that your Committee suggested that a member of the staff of the Bureau of Standards present a brief review of the factors that enter the radiator problem.

RADIATOR PROBLEM FACTOR

Our work at Washington has been primarily with respect to an application of these factors to aircraft, but the principles are the same as in the tractor problem, of course. There is a widely different application, but the fundamentals are the same. The methods that we followed in studying the factors for aircraft may be more or less similar to the methods that the tractor engineers will find worthwhile to use in attacking their problem. First, we had to consider from the purely engineering point of view, rather than from that of the details of a scientific study, what properties of a radiator have a bearing upon the problem. In my own analysis, I sketched six different considerations that should come in for the aircraft problem: (*a*) cooling capacity, (*b*) head-resistance, (*c*) weight, (*d*) appearance, (*e*) sturdiness of construction and ease of repair and, finally, (*f*) the cost. There we have six different problems interlocked. From the standpoint of aircraft radiators certain of these factors were of importance and others were not. For example, with the aircraft we could forget all about cost; we were working then primarily on the military machines and even if the radiator did cost 5 to 10 times more, it might soon save that cost in operating because of the greater reliability of the airplane. From every military consideration, cost was a very unimportant thing. In the commercial applications, where large quantities of passenger automobiles or tractors are produced, cost becomes one of the factors of great importance. The appearance of aircraft was something that we could neglect. Head-resistance was a matter of prime importance, and so was weight. Our problem, therefore, involved head-resistance, cooling capacity and weight.

Let us turn to the automobile industry, which preceded that of aircraft. Head-resistance is of small importance in the automobile, but the question of appearance is of very great moment, as the sales department of any automobile company will testify. It is something the engineer must take into consideration. Sturdiness and ease of repair never required undue attention on our part, not because the factor is unimportant, but because inventive ingenuity seems to have mastered that factor in almost any type of radiator core one can picture. In aircraft work it requires perhaps somewhat less than in the other cases because the air machines usually receive rather expert attention, but for the automobile or tractor I think sturdiness and ease of repair would be given a very prominent place. We can eliminate head-resistance from the scientific questions and, for the tractor, we can give comparatively little emphasis to weight; so that cooling capacity, it seems to me, is the only one that remains. That is, we want to consider cost as opposed to getting the radiator properly sturdy, properly accessible for repair and proper as regards cooling capacity. There are those four factors.

The scientific work that has been done in various laboratories of the industry, in the United States and in Europe, has given us comparatively little data on the radiator. We know in very general terms the conditions under which the radiator is working, but we have very few data as to just what specifications describe those conditions for the passenger automobile or for the tractor. So, our work at the Bureau of Standards, which was primarily with respect to aircraft, included a very careful study of the conditions under which the aircraft radiator would work; that is, primarily, how much air would go through the radiator. I think all the data regarding cooling that we have will be found directly applicable to the passenger automobile or tractor, just as soon as we have solved the other half of the problem, namely, what the conditions of airflow are in such types of radiator. While some of the industrial laboratories have done considerable work on that, it is my understanding that the reason the Tractor Division of the Society's Standards Committee is not getting very far in adopting any standards and definite specifications in the radiator problem is that there is a very small amount of correlated data as to the conditions of airflow in the different types of radiator as mounted in the various makes of car. The amount of heat that a radiator will dissipate depends primarily on the weight of air that is going through it. It is not directly proportional to airflow but, over moderate ranges of variation in flow, it is not very far from that.

Our work on the aircraft radiators in which air was forced through them at wind speeds of from 20 to 120 m.p.h. showed that for almost every type of core we tried, including some 70 or 80 types, a numerical equation would express the heat-transfer in which the term of which we are now speaking, the airflow per unit area, entered in a relation where it was raised to a constant power, generally about the eight-tenths power. That is, the total heat dissipated by the core, with all things constant except airflow, varied as the eight-tenths power of the airflow through the radiator. If a radiator is mounted on the front of an automobile and pushed through the air at a given driving speed without having the fan going, it does not mean that, of necessity, the air goes through the radiator at anything like the driving

speed. It will generally be less than the speed of the radiator relative to the air. One factor to bear in mind is that one cannot always deduce simply what conditions are being obtained for airflow through a radiator core from what is known of wind speed in front or behind that core. What we want to measure is the actual airflow through the core, not the airflow somewhere in front of the radiator, or at some certain distance behind it. Since the one definite factor to which we can tie in such work is the rate of airflow, we must always be able to specify the airflow through the core to apply any data that have been obtained, as, for example, our data on the aircraft-radiator work. Whenever, then, for the automobile or the tractor radiator, we have any data giving the airflow, this quantity raised to about the eight-tenths power is the factor to which the heat transfer is proportional. So, if we operate a fan so as to draw four times as much air per minute through it at one time as at another, we get about three times the heat transfer. While you thus see that the relation is not proportional, it is not far from it and we can have in mind that it is more or less approximately so and that if we double the airflow through the core we will nearly double the heat that will be taken away from the water for a certain surface and a given temperature-difference of the water and the air. The factor that seems to have received too little attention in the engineering consideration of this problem is the influence of the air-flow through the core. For example, very little attention has been paid to what becomes of the air after the fan has sucked it through the core; yet if the efflux openings are blocked up too much, we will have a back-pressure that makes the actual air that comes through the core very much less than the same fan at the same speed would pull through it in the open. For such reasons a wind-tunnel experiment under conditions that were erroneously supposed to be approximately similar to practical working conditions, is sometimes misinterpreted. So, as you go through these newer problems, the applications to the tractor-radiator design, do not forget the importance of the airflow through the core. The frontal area that is required will depend absolutely on what airflow is obtained through it. If we are to get twice as much air, we can cut down the frontal area by half. Head-resistance makes no difference in tractor work. There can be a large frontal area and a small depth, or a small frontal area and a large depth. It is a matter of convenience whether the radiator will be accessible; the one factor that is vital is that we get the airflow that will correspond to the frontal area and depth.

The question of waterflow or, more generally, if anti-freeze mixtures be used, the rate of fluid flow requires comparatively little attention, I think. We found in our work with the aircraft radiators that if the waterflow exceeded about 15 gal. per min. for 1 ft. width of core, where the core was about 4 or 5 in. deep, any waterflow in excess of that amount did not bring heat to the metal any faster than the air could take it away, for the ordinary core of any type considered. The usual pump system is delivering water at fully that speed, and the question of waterflow is principally that of having the passages wide enough that they will not clog. The whole problem of radiator action comes in getting the heat in the metal out to the air, and not in getting it from the water to the metal. The specific heat has importance in its bearing on the actual quantity of fluid that must be circulated, but the thermal conductivity can be minimized to a considerable degree. As I said, the fluid tends to get the heat into the metal so much faster than the air will take it away, that even with the great variation of conditions we encounter there is almost never a really significant difference in the temperatures of the metal and the water. Therefore, if we used a liquid of very much poorer thermal transmission properties, there would still be comparatively little temperature-drop between the metal and the liquid. The viscosity of any fluid other than water might have a considerable bearing on the rate of circulation, and upon the way the pump would work, and thus be very important in secondary ways, but it would hardly be a prominent factor in the heat-transmission considerations.

PROF. C. A. NORMAN:—I understand that the engineers of the London General Omnibus Co. have found that alcohol corrodes metal very badly. What observations have been made as to the possible corrosive action of these anti-freezing mixtures on the metal used in the radiators?

MR. HARPER:—With regard to corrosion, the chief difficulties have been stated to the Bureau of Standards to lie in the serious effects on copper and brass, rather than with the iron in the cooling circuit. I do not know how serious the trouble has been with radiators themselves, having had no occasion to take radiators apart that have had alcohol in them. I know something of corrosion from using alcohol in systems comprising copper and brass, and I feel it proper to express an opinion that it is necessary to consider corrosion more carefully as we come to more extended uses of alcohol. However, regarding the use of alcohol in radiators, I imagine that the degree of dilution decreases the corrosion factor very considerably, although I cannot be taken as an authority on this subject of corrosion.

CASEIN GLUES

CASEIN glues are as a class more water-resistant than animal and vegetable glues, but they are not, strictly speaking, waterproof. There is no glue that is unaffected by water, after a long immersion. Nevertheless, there are casein glues that are so water-resistant that plywood glued with them will withstand soaking for many weeks in water or exposure for many months to a warm, damp atmosphere. Under similar conditions animal and vegetable glues would lose their strength in a comparatively short time.

When casein-glue joints are kept fairly dry, they can be expected to retain their strength and remain unchanged for an indefinite period, as is the case with animal and vegetable glues. Water-resistant casein glue in a joint, kept constantly wet, will after a long time weaken, but it will ordinarily regain a considerable proportion of its strength if the joint is dried. In a study aimed to discover the reason casein glues ultimately decompose when kept moist, the Forest Products Laboratory, Madison, Wis., found that under certain condition the decomposition seemed to be due to a hydrolysis of the casein, undoubtedly brought about by the sodium hydroxide that is always present in casein glues. This should not be taken to mean that casein glues are unreliable and not durable enough for use in manufacturing plywood and other glued products. On the contrary casein glues are considered by the Laboratory as enduring as any under dry conditions, and the water-resistant casein glues are more enduring than animal or vegetable glues under wet or damp conditions.

Condensation Temperatures of Gasoline and Kerosene-Air Mixtures[1]

By Robert E. Wilson[2] and Daniel P. Barnard, 4th[3] *Illustrated with* Drawing and Charts

AFTER pointing out that a very important factor in connection with carbureter and intake-manifold design and the automotive fuel problem in general is a knowledge of the temperatures at which air-fuel mixtures either begin to condense or are completely vaporized, a new, simple and reliable method for determining the temperatures of the initial condensation of fuels from air-fuel mixtures is described, together with an approximate method of determining the temperatures of partial condensation in such mixtures. Vapor-pressure data on three typical automotive fuels are presented, supplemented by a series of charts showing the condensation temperatures of kerosene, gasoline and an artificially prepared high end-point gasoline under different conditions. It is pointed out in connection with the charts that inefficient methods of securing vaporization are responsible to a greater extent for the failure to obtain complete vaporization of present-day gasoline than any inherent limitation of the fuel itself.

A suggested method for approximating roughly the initial-condensation temperatures of paraffin hydrocarbon fuels from their distillation curves is outlined. A table giving the more important characteristic properties of the fuels investigated is included.

A KNOWLEDGE of the temperature at which various mixtures of internal-combustion engine fuels and air are completely vaporized, or just begin to condense, is of great importance in connection with the design of carbureters and intake manifolds and the automotive fuel problem in general. To secure satisfactory distribution between the different cylinders a fuel must be completely vaporized. This can be accomplished by heating the fuel, the air or the resulting mixture. If, however, the amount of heating is more than that required to vaporize the fuel, serious losses are encountered from the decreased capacity of the engine for the hot mixture, and the increased tendency toward knocking. From this standpoint it is important to know what minimum temperature must be reached to make complete vaporization possible, and then improve the efficiency of the mechanical devices for the vaporization of the fuel until substantially complete vaporization is obtained without appreciably exceeding this theoretically minimum temperature.

The suitability of kerosene and other fractions as fuels for internal-combustion engines, the proper end-point for gasoline and other important fuel problems depend to a considerable extent upon the dew-point of the fuel-air mixtures, that is, the temperature at which vaporization is complete or at which condensation begins on cooling.

In spite of the obvious importance of this information the authors have been unable to find any published information as to the dew-point of mixtures of the commoner fuels with air in the customary proportions. In fact, practically the only discussion of the problem is a very interesting paper[4] by Frank A. Howard entitled the Volatility of Internal-Combustion Engine Gasoline. This paper points out the importance of the problem and describes some experiments on gasoline which lead to certain practical conclusions. Although these conclusions are sound, the experimental results do not give any definite information as to the condensation point of gasoline under service conditions. There appear to be no data whatever on kerosene-air mixtures.

Methods of Determining the Condensation Points of Fuel-Air Mixtures

The most direct method of determining the dew-point of mixtures of air and gasoline would be to introduce a small, accurately weighed amount of gasoline into a flask containing a known volume of air, close all outlets, raise the temperature of the mixture until the gasoline was completely vaporized, and then cool very slowly until a mist of gasoline began to deposit on the walls of the flask; or better, on an internally cooled mirror, such as that used by McBain[5] in his work on soap solutions. By recording the pressure and temperature at which condensation began it should be possible to obtain a fairly accurate value for the dew-point of a particular mixture at a given pressure. The most serious objection to this method lies in the fact that a new sample must be weighed out accurately for each separate determination and that a large number of determinations must be made to determine the properties of a given fuel over the ordinary range of mixture ratios and pressures which are of interest. The Bureau of Standards has made some determinations by this method, but reports that the results thus far obtained are not considered satisfactory.

It might be suggested that the desired information could be obtained more simply by making vapor-pressure measurements, as in the case of pure compounds. The difficulty involved in this suggestion is the fact that gasoline is a mixture of compounds that differ widely in volatility and the vapor pressure of the original gasoline bears no relation to the vapor pressure of the fraction that first condenses out on cooling a completely vaporized mixture. If, however, it were possible to secure any considerable quantity of this fraction that first condenses out from, and hence is in equilibrium with, the completely vaporized mixture, measurements of its vapor pressure would obviously give the data desired.

It might at first sight be assumed that the composition of the fraction that first condenses out would be the same as that which was last distilled off in an ordinary distillation; but this is far from being the case, as a little consideration will show. The material that last distills out of the flask is in equilibrium with the vapor that is leaving the flask at that moment, and not with the completely vaporized gasoline as a whole. For this reason

[1] From a paper presented at a meeting of the American Chemical Society.

[2] Director of research, Massachusetts Institute of Technology, Cambridge, Mass.

[3] Research associate, Massachusetss Institute of Technology, Cambridge, Mass

[4] See The Journal, February, 1921, p. 145.

[5] See *Journal of American Chemical Society*, vol. 42, p. 426.

the data obtained by Howard on the vapor pressure of the least volatile portion of the gasoline, the last 10 per cent distilled off, do not in any sense determine the temperature at which the mixture as a whole would begin to condense.

If a large volume of completely vaporized gasoline were run through a condenser whose temperature was gradually lowered until condensation just began, it is conceivable that a small amount of condensate might be secured that would represent fairly well the composition of the equilibrium mixture whose vapor pressure is desired. Any such device would, however, be open to serious question because of the necessary existence of a temperature gradient from the center of the stream to the walls, and the probability is that most of the condensate would come from that part of the vapors nearest the walls, and would not be in true equilibrium with the mixture as a whole. On account of these difficulties, the

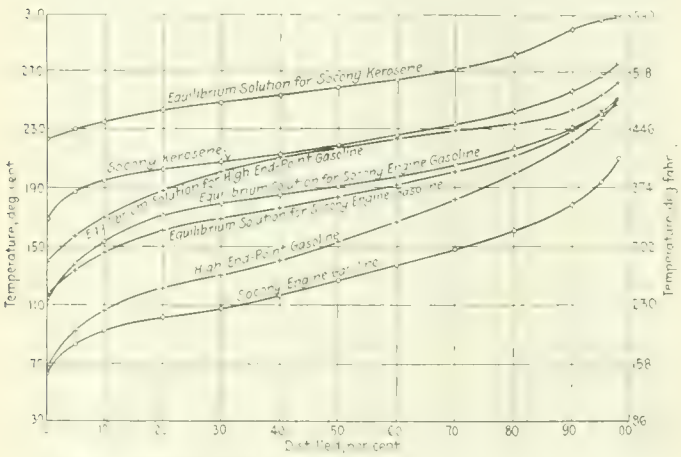

Equilibrium Solution for Sarony Kerosene
Sarony Kerosene
Equilibrium Solution for High End-Point Gasoline
Equilibrium Solution for Sarony Engine Gasoline
Equilibrium Solution for Sarony Engine Gasoline
High End-Point Gasoline
Sarony Engine Gasoline
Temperature, deg. cent.
Temperature, deg. fahr.
Per cent by volume

FIG. 1—DISTILLATION CURVES OF VARIOUS FUELS AND THEIR EQUILIBRIUM SOLUTIONS

Massachusetts Institute of Technology laboratory has developed a new method of obtaining a considerable amount of the desired equilibrium solution and by measuring its vapor pressure is able to calculate accurately the initial condensation temperature for any given mixture and the total pressure within the range of ordinary practice. By combining these data with data on the vapor pressure of the original gasoline it is also possible to determine approximately the percentage condensed under any given set of conditions.

It must be emphasized at the outset that results secured by such methods represent the conditions prevailing at equilibrium. It is possible to obtain "wet" mixtures at temperatures well above the dew-point, because the drops of the fuel that are sprayed into the airstream do not have sufficient time to absorb heat and vaporize before the mixture reaches the engine. The results simply indicate what is theoretically obtainable if the time, the degree of atomization, etc., are sufficient to permit equilibrium to be approached fairly closely.

Practical experience with present-day fuels indicates that on account of the limited time available it is necessary to separate out and apply heat to the unvaporized drops by direct contact with metal surfaces, as in various types of hot-spot manifolds, etc.

EXPERIMENTAL METHODS

In this work three different representative fuels were selected for investigation; their distillation curves are shown in Fig. 1. The gasoline had an initial boiling-point of 60 deg. cent. (140 deg. fahr.) and an end-point of 211 deg. cent. (411.8 deg. fahr.) and a specific gravity of 0.743. Its average boiling-point is fairly typical, but its boiling range is somewhat narrower than the average present-day product. The initial boiling-point of the kerosene was 168 deg. cent. (334.4 deg. fahr.), the end-point 282 deg. cent. (539.6 deg. fahr.), and the specific gravity 0.800. An artificially prepared high end-point gasoline consisting of a blend of 100 parts of engine gasoline and 25 parts of the lighter 50 per cent fraction obtained by distilling kerosene at atmospheric pressure was investigated. The initial boiling-point of this mixture was 62 deg. cent. (143.6 deg. fahr.), the end-point 252 deg. cent. (485.6 deg. fahr.), and the specific gravity 0.752.

To calculate the partial pressure of the fuel in a 15 to 1 mixture it is necessary to know the approximate average molecular weight of the fuel. The average molecular weights as used in this work were determined with sufficient accuracy by first obtaining their distillation curves and from these curves plotting the differential distillation curves shown in Fig. 2. This form of the distillation curve, obtained from the customary form by plotting the percentage coming over between each 10 deg. cent. or 20 deg. fahr. against the median boiling-point of the fraction, plotting the percentage over between 80 and 90 deg. cent. (176 and 194 deg. fahr.) against the temperature of 85 deg. cent. (185 deg. fahr.) is much more useful in comparing different fuels and detecting the presence of added constituents, such as benzene, that give a sharp peak in the curve near their boiling-points. Rigidly this method is undoubtedly inaccurate but, since an error of 10 per cent in the molecular weights would change the condensation temperatures by only 2 or 3 deg., it was not considered worthwhile to spend the amount of time involved in an accurate determination, especially in view of the great variations between different samples of commercial gasolines. The average boiling-point was taken as the point at which a perpendicular passed through the center of gravity of the area bounded by the curve and the X-axis cut this axis. The distillation tests were made in a standard Engler still, using 100-cc. (6.1-cu. in.) samples. The average boiling-points determined as stated above, and the molecular formulas and weights of saturated paraffin hydrocarbons most nearly, within 2 or 3 deg. cent. (3.6 or 5.4 deg. fahr.), corresponding to these weights, are given in Table 1.

TABLE 1—PROPERTIES OF FUELS TESTED

Fuel	Kerosene	Gasoline	High End-Point Gasoline
Average Boiling-Point, deg. cent.	220.0	128.0	147.0
Average Boiling-Point, deg. fahr.	428.0	262.4	296.6
Corresponding Formula	$C_{12}H_{26}$	C_8H_{18}	C_9H_{20}
Average Molecular Weight	170	114	128

The partial pressures of the fuels in the different mixtures were calculated after the following example for a 15 to 1 kerosene-air mixture in which the partial pressure of kerosene at a total pressure of 1 atmosphere is equal to

$$[(1/170) \div (1/170 + 15/29)] \times 760 = 8.55 \text{ mm.}$$

As has been pointed out, to determine the initial condensation point of a fuel-air mixture it is necessary to prepare a considerable amount of a so-called "equi-

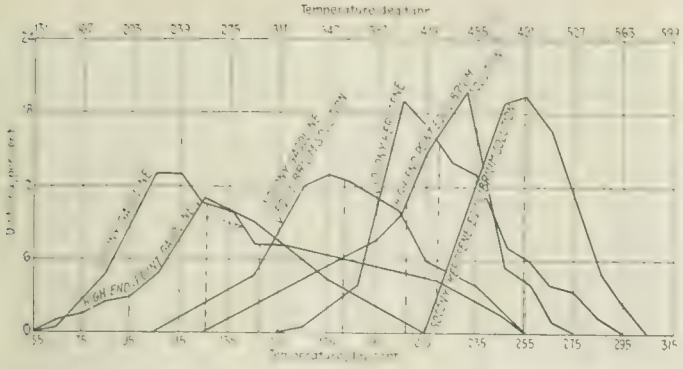


FIG. 2—DIFFERENTIAL DISTILLATION CURVES OF VARIOUS FUELS AND THEIR EQUILIBRIUM SOLUTIONS

librium solution" whose composition is in precise equilibrium with the uncondensed fuel at its dew-point. This solution was prepared in a glass still arranged for continuous operation as shown at the left of Fig. 3. The amount of liquid in the flask was kept constant at all times by carefully adjusting the rate of supply to that of condensate discharge, the level being measured by a small glass hook gage. The temperature of the oil-bath was also kept fairly uniform.

At first the composition of the fuel in the flask, as well as consequently its boiling-point, was identical with that of the original fuel; the vapor that passed off was, however, richer in the more volatile constituents, and hence as the distillation proceeded the solution contained more and more of the less volatile materials and its boiling-point rose. After four or five times as much liquid had passed through the flask as was held there, the temperature of the boiling liquid soon reached a constant maximum-point, after which the distillation was continued, keeping all conditions constant, until two or three more times the volume of the liquid in the flask had been distilled over.

By this time a dynamic equilibrium had certainly been definitely established, and since input must equal output, the composition of the vapor leaving the flask must then have been exactly equal to that of the original liquid entering. But the liquid in the flask was in equilibrium with this outgoing vapor, and it therefore had the same composition as that of the liquid that would first condense out from the vapor at its dew-point. Furthermore, enough of the liquid was then secured not only to measure its vapor pressure, but also to determine its distillation range compared with that of the original fuel.

The only remaining uncertainty involved is whether the composition of this equilibrium mixture is substantially the same at different temperatures. To settle this point two equilibrium solutions were prepared from the same gasoline, one with the flask at atmospheric pressure, and one at about 13-cm. (5.1181-in.) absolute pressure, this changing the boiling-points by about 60 deg. cent. (140 deg. fahr.). The distillation curves for these two solutions are given in Fig. 1. Careful measurement of the vapor pressures showed that the variations between the dew-points as determined from the two solutions in no case exceeded 3 deg. cent. (5.4 deg. fahr.). All other equilibrium solutions were prepared at about 13-cm. (5.1181-in.) pressure, so as to approach reasonably closely to the comparatively low temperatures at which condensation takes place from air-fuel mixtures.

It will be noted from the differentiated form of the distillation curves shown in Fig. 2 that the average boiling point of the equilibrium solution falls approximately at the 85-per cent point of the original fuel, and contains a considerable amount of material boiling as low as the 50-per cent point. This would be expected, since the first per cent or two distilling off of the equilibrium solution should have the same composition and average boiling-point as that of the original solution. The presence of some of the more volatile constituents is, of course, due to the fact that they dissolve in, and have their vapor pressure lowered by, the less volatile constituents. The foregoing illustrates the fallacy of assuming that the extreme high end of the distillation curve determines the initial condensation temperature of the fuel, or that any arbitrary selection of a high fraction of fuel can properly represent the composition of the equilibrium solution.

Two vapor-pressure curves for each fuel were experimentally determined; the vapor-pressure curve of the original fuel, which corresponds to the vapor pressure exerted by the completely condensed fuel; and the vapor-pressure curve for the equilibrium solution which represents the first drop that condenses out of a completely vaporized mixture.

The vapor pressures were measured at different temperatures in the apparatus sketched at the right of Fig. 3. The bulb was about 80 per cent filled with the liquid to be measured, and the U-tube was half-filled with mercury. This U-tube, being immersed in the constant-temperature bath, served to prevent the vapor from condensing in the manometer, as it would otherwise do. The pressure in the space between the U-tube and the manometer was adjusted by the stopcocks, so as to keep the liquid in the U-tube exactly level whenever readings were taken. The pressure exerted by the liquid was then equal to the barometer reading minus the difference between the height of the two manometer columns. Care was taken, when starting a series of observations, to boil off under a high vacuum a very small part of the liquid, to free the apparatus of all traces of air. As the bulb held about 40 cc. (2.441 cu. in.) and the amount lost in this manner was never over 0.2 cc. (0.0122 cu. in.), the error involved was so small as to be entirely negligible.

Most of the measurements were made by increasing the temperature in a stepwise fashion, only a few minutes being required to reach equilibrium at a given temperature. All results were checked by repeating the experiments on separate samples. It was found impracticable to check all points by lowering the temperature in a stepwise fashion, as temporary condensation of the vapor in the glass walls of the vessel and in the manometer arm, instead of in the liquid of the flask, made

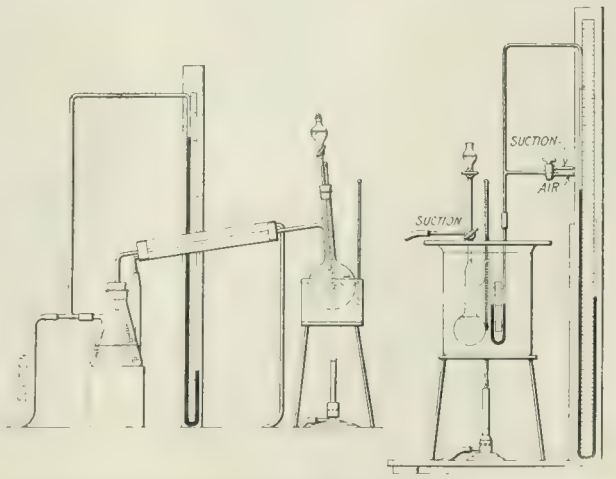


FIG. 3—APPARATUS AT THE LEFT FOR THE PREPARATION OF THE EQUILIBRIUM SOLUTIONS AND AT THE RIGHT THAT EMPLOYED FOR DETERMINING THE VAPOR PRESSURE

necessary a long wait before equilibrium was obtainable. In two attempts that were made to check by this means the pressure reading kept dropping very slowly for over 1 hr., but finally reached an equilibrium value which approximated very closely the value obtained in a much shorter time by raising the temperature.

To make possible a critical study of the vapor-pressure observations and also extrapolations of them with much greater accuracy than is obtainable on an ordinary vapor-pressure plot where the curvature is high, the results of observations were plotted on semi-logarithmic paper, the vapor pressures being plotted along the log scale, against the reciprocals of the absolute temperatures in degrees Kelvin along the arithmetic scale. Then if the modified form of the Clapeyron equation, which assumes the validity of the perfect gas law, holds for the mixture in question, the experimental points plotted as stated above should lie along a straight line if the heat of vaporization of the liquid is constant over the temperature range covered, or along a slightly curved line if the heat of vaporization varies with the temperature.

The fact that these log plots are straight lines, which is probably true only for fuels which consist essentially of similar hydrocarbons, and not for blends containing benzene, alcohol, etc., indicates that the heat of vaporization is actually substantially constant over the temperature range covered, and this in turn means that the specific heats of the liquid and vapor at any given temperature are nearly equal. The fact that the points all lie on a straight line makes possible the accurate extrapolation of the vapor-pressure curve into the low-pressure range, where, because of their small magnitude, the pressures are relatively difficult to measure with precision. As the gas laws hold more and more rigidly the lower the pressures, these extrapolated curves are much more accurate than could be determined experimentally without the use of special apparatus.

As is pointed out in the succeeding article, the heats of vaporization as determined from the slopes of these curves agree very closely with those determined by calorimetric methods by different investigators.

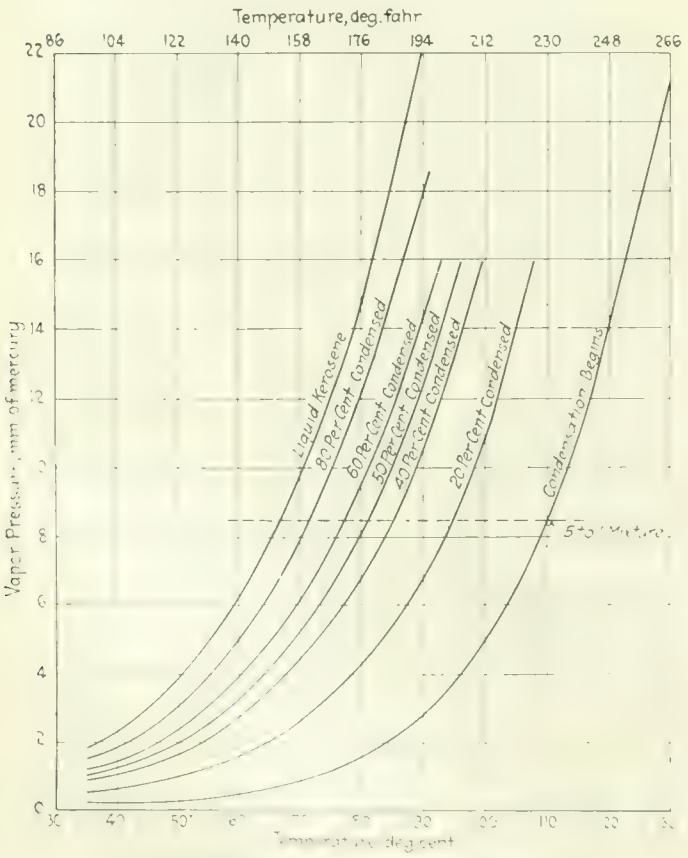


FIG. 4—VAPOR-PRESSURE CURVES FOR KEROSENE

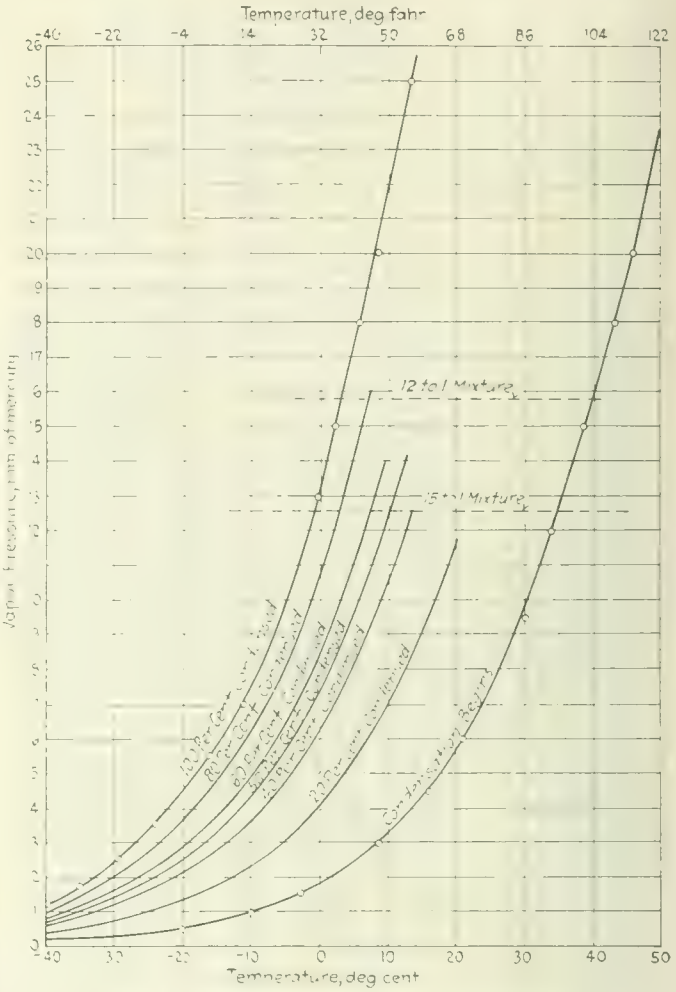


FIG. 5—VAPOR-PRESSURE CURVES FOR GASOLINE

The upper curves on the log plots, the vapor-pressure curve for the equilibrium solution, represent the vapor pressures of the first drop which condenses out of an air-fuel mixture. The lower curves for the original fuel represent the vapor pressures of the 100-per cent condensed liquids. Experimental determinations of the vapor pressures of partially condensed vapors would be extremely difficult. Approximate figures for the various partial-condensation temperatures were therefore determined by assuming that the liquid obtained by condensing 40 per cent of the vapor exerted a pressure corresponding to a value 40 per cent of the distance from the totally vaporized line to the completely condensed line. The various figures for "per cent condensed" used hereinafter refer to the percentage lowering of the partial pressure and hence of the number of molecules of the vapor in the air, rather than the percentage by weight of liquid recovered. Since the first part of condensate consists on the average of heavier molecules, 50 per cent condensed in the above described sense would correspond to possibly 55 per cent by weight condensed. A study of the accurate data available in the literature on the vapor pressure of mixtures of octane and decane showed that

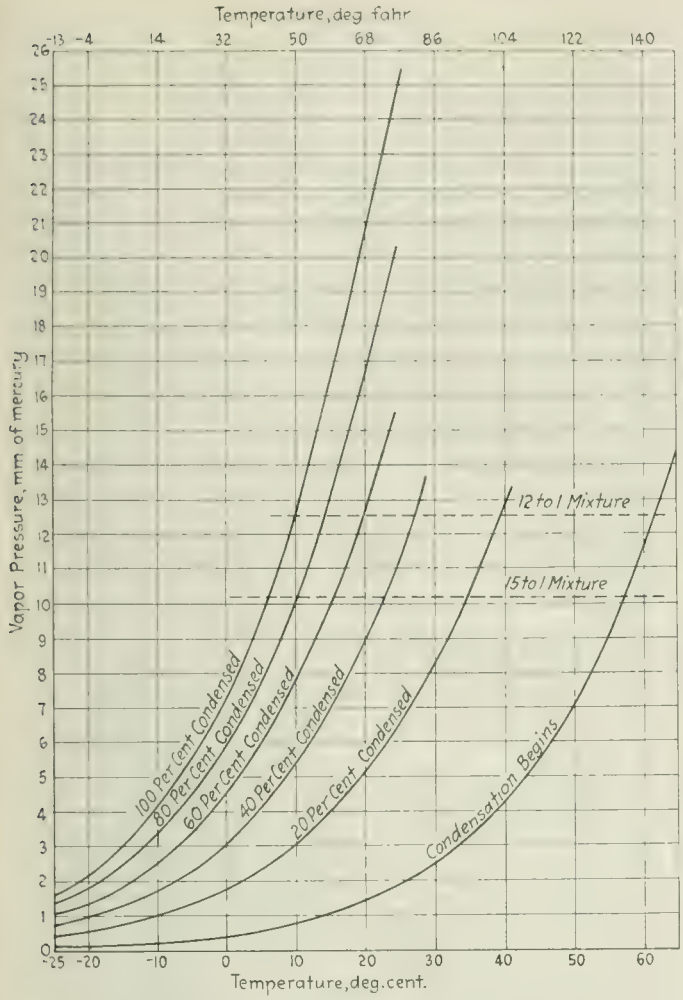

Temperature, deg fahr
-13 -4 14 32 50 68 86 104 122 140
Vapor Pressure, mm of mercury
Temperature, deg. cent.
12 to 1 Mixture
15 to 1 Mixture
100 Per Cent Condensed
80 Per Cent Condensed
60 Per Cent Condensed
40 Per Cent Condensed
20 Per Cent Condensed
Condensation Begins

FIG. 6—VAPOR-PRESSURE CURVES FOR A MIXTURE COMPOSED OF 100 PARTS OF GASOLINE AND 25 PARTS OF KEROSENE

this held true to within 5 or 6 per cent. This is certainly near enough to the truth for the purpose at hand, as far as paraffin hydrocarbons are concerned. Figs. 4, 5 and 6

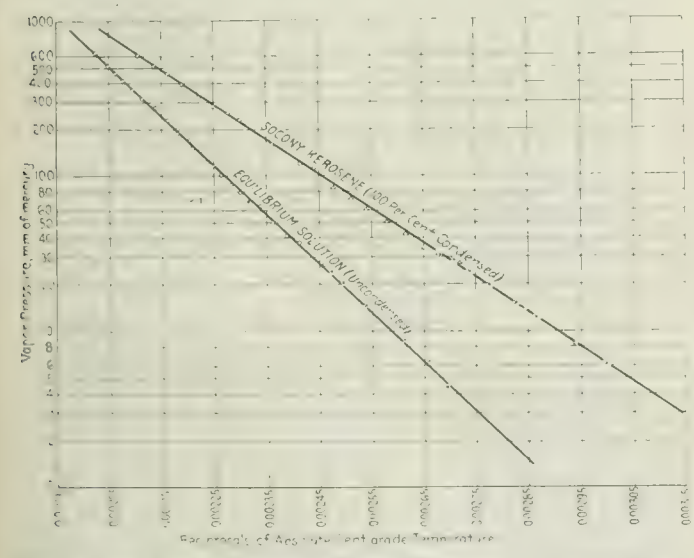


FIG. 7—LOGARITHMIC CURVES OF VAPOR PRESSURE OF KEROSENE AND ITS UNCONDENSED EQUILIBRIUM SOLUTION

show the vapor pressures exerted by the various fuels, when condensed to different extents, over the range covered by the air-fuel mixtures used in internal-combustion engines, plotted directly against the temperatures in degrees centigrade. To determine, for example, the temperature at which kerosene is 40 per cent condensed from a 15 to 1 mixture at 1 atmosphere pressure, it is only

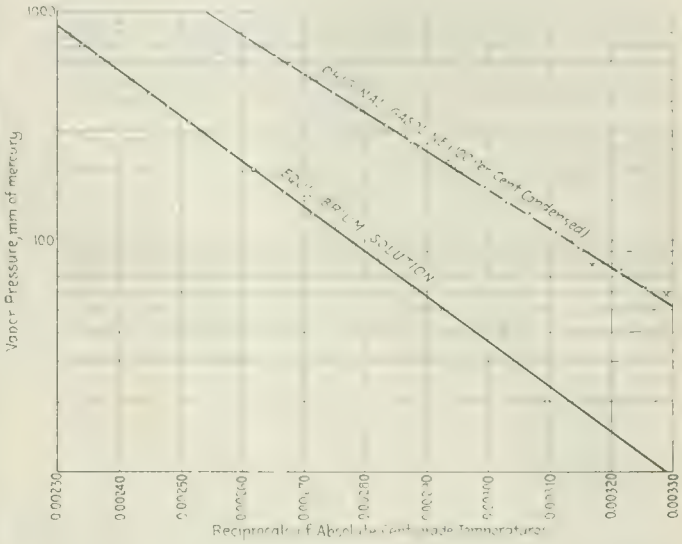


FIG. 8—LOGARITHMIC CURVES OF THE VAPOR PRESSURE OF GASOLINE AND ITS EQUILIBRIUM SOLUTION

necessary to find the temperature corresponding to the point on the "40-per cent condensed" curve which indicates a vapor pressure equal to 60 per cent of the vapor pressure of the entirely vaporized fuel, in this case 8.55 mm.

$$0.60 \times 8.55 \text{ mm.} = 5.10 \text{ mm.}$$

5.10 of the "40-per cent" curve corresponds to a temperature of 73 deg. cent. (163.4 deg. fahr.). Kerosene is therefore approximately 40 per cent condensed from a

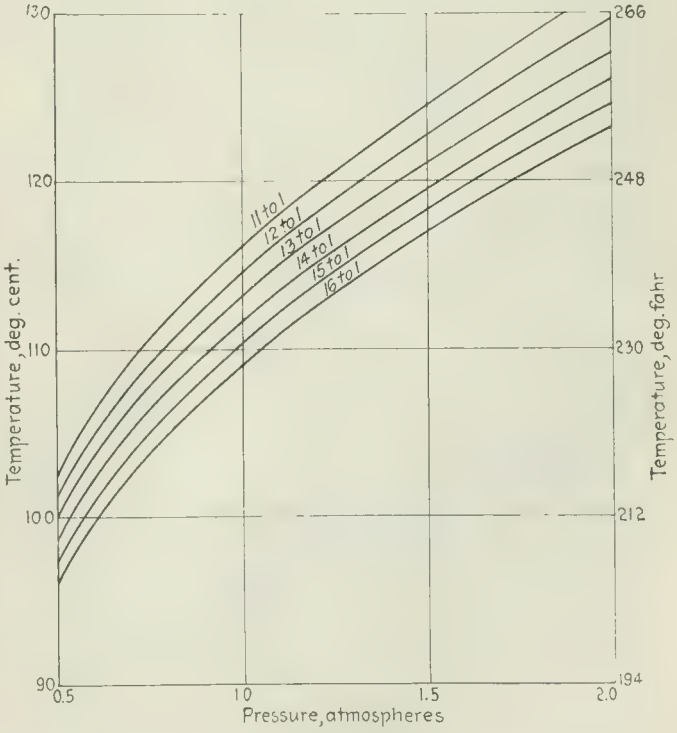


FIG. 9—CURVES OF INITIAL CONDENSATION TEMPERATURES FOR VARIOUS KEROSENE-AIR MIXTURES

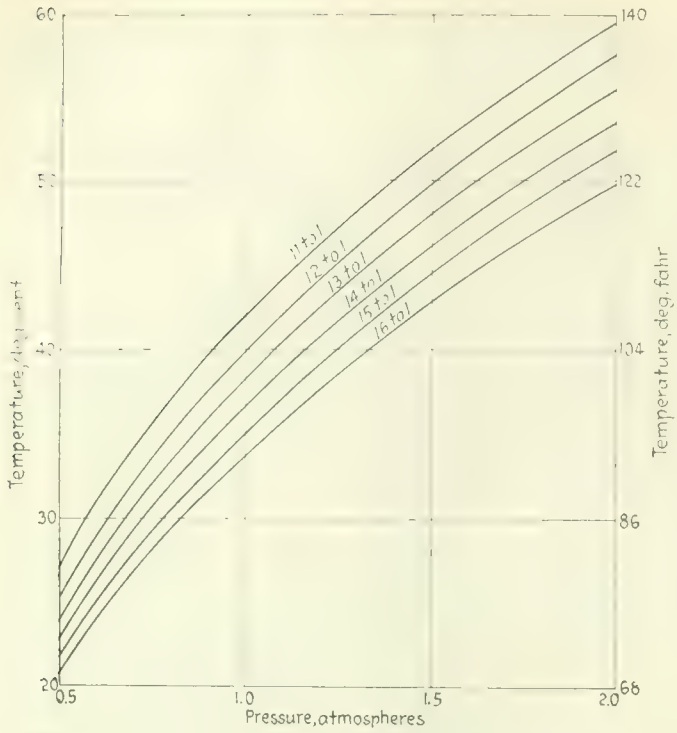


FIG. 10—CURVES OF INITIAL CONDENSATION TEMPERATURES OF VARIOUS GASOLINE-AIR MIXTURES

15 to 1 mixture under 1 atmospheric pressure at a temperature of 73 deg. cent. (163.4 deg. fahr.).

DISCUSSION OF RESULTS

The data are all presented in graphic rather than tabular form and are for the most part self-explanatory. The experimentally determined vapor-pressure values are indicated on the log plots, Figs. 7 and 8. It will be noticed that they fall very satisfactorily on straight lines. Although the lines appear to converge before reaching the zero axis, if measurements had been made at pressures above 1.5 atmospheres it is probable the lines would have begun to curve apart, due to large deviations from the perfect gas laws.

Figs. 4, 5 and 6 are replotted directly from the best representative lines on the log plots, and Figs. 9, 10 and 11 are plotted from values calculated as indicated above from the vapor-pressure curves.

These curves, as their titles indicate, show respectively the initial condensation temperatures for kerosene and gasoline under different pressures over the range from 0.5 to 2.0 atmospheres, and the temperatures of partial condensation at atmospheric pressure for all three fuels for a 12 to 1 and a 15 to 1 air-fuel mixture, representing fairly closely the composition for maximum power and theoretically perfect combustion respectively.[6]

These results indicate clearly that any difficulties in securing complete vaporization of the present commercial gasoline are not due to any inherent limitation in the gasoline itself, or to too low manifold-temperatures, once the engine is warmed up. Indeed, where any serious attempt has been made to heat the incoming gases or the intake-manifold, the temperature attained by the airstream is almost invariably far higher than theoretically necessary. Improvement in vaporization should apparently be secured by better atomization, longer times of contact or by throwing the unvaporized particles out of the insulating airstream on to a hot-spot, rather than by raising the temperature of the mixture as a whole, with the attendant disadvantages of this.

With the same precautions as suggested above, raising the temperature of the intake-manifold only slightly above present practice should make possible the utilization of fuels of considerably higher end-point, as far as completeness of vaporization and proper distribution are concerned.

It will be noted from the curve in Fig. 2 that the

[6] See *Journal of Industrial and Engineering Chemistry*, vol. 13, p. 51, and THE JOURNAL, June, 1921, p. 543.

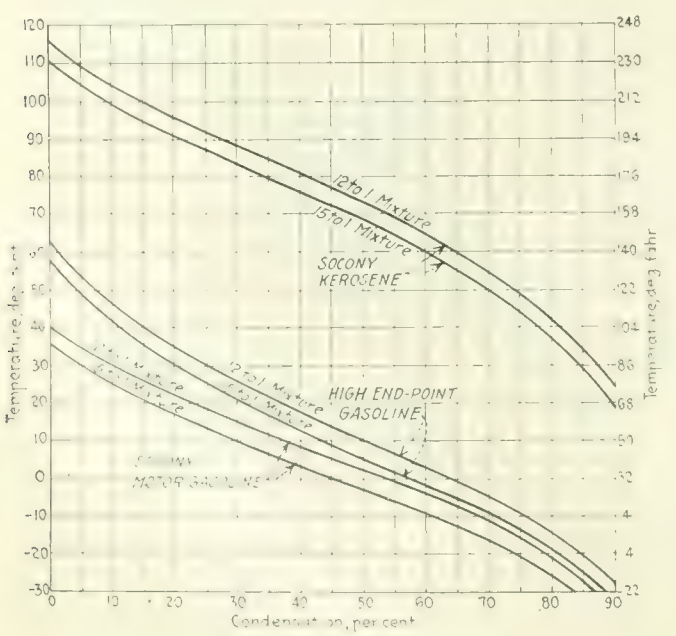


FIG. 11—CURVES OF PARTIAL CONDENSATION TEMPERATURES OF AIR-FUEL MIXTURES

TABLE 2—SUMMARY OF THE PHYSICAL CONSTANTS OF THREE TYPICAL FUELS AND THEIR MIXTURES WITH AIR

Fuel	Fuel Gasoline	High End-Point Gasoline	Kerosene
Average Boiling-Point, deg. cent.	128.0	147.0	220.0
Average Boiling-Point, deg. fahr.	262.4	296.6	428.0
Average Molecular Weight	114	128	170
Corresponding Formula	C_8H_{18}	C_9H_{20}	$C_{12}H_{26}$
Specific Gravity at 20 deg. cent. (68 deg. fahr.)	0.743	0.752	0.800
Baumé Gravity, deg.	60	57	45
Initial Boiling-Point, deg. cent.	60	62	168
Initial Boiling-Point, deg. fahr.	140	144	334
50 Per Cent Distilled, deg. cent.	128	154	219
50 Per Cent Distilled, deg. fahr.	262	309	426
85 Per Cent Distilled, deg. cent.	169	208	249
85 Per Cent Distilled, deg. fahr.	336	403	480
End-Point, deg. cent.	211	252	282
End-Point, deg. fahr.	412	485	539
Initial Condensation Temperature from 12 to 1 Mixture, deg. cent.	40	63	116
Initial Condensation Temperature from 12 to 1 Mixture, deg. fahr.	104	134	242
50 Per Cent Condensed from 12 to 1 Mixture, deg. cent.	2	9	73
50 Per Cent Condensed from 12 to 1 Mixture, deg. fahr.	36	48	163

average boiling-points of the equilibrium mixtures fall very close to the temperature at which 85 per cent of the original fuel has been boiled off, as indicated by the standard distillation curves. There is apparently some, though a not at all rigid, connection between these two points, for if, in each case, 135 deg. cent. (243 deg. fahr.) be subtracted from the "85-per cent off" temperature, the result is a rough approximation, within 5 or 10 deg. cent. (9 or 18 deg. fahr.) to the initial condensation temperature of a 12 to 1 mixture at 1 atmosphere. This fact may serve as a means of estimating roughly the initial condensation temperatures of paraffin hydrocarbon fuels from a mere inspection of their distillation curves. The reason for this rather surprising relationship probably lies in the approximate equality of the heats of vaporization, and hence of the rate of change of vapor pressure with temperature, of the paraffin hydrocarbons. It would certainly not apply to fuels containing alcohol, benzene, etc.

Attention should be called also to the fact that the temperature at which the various original fuels exert a given vapor pressure is a comparative measure of the ease of starting in cold weather, provided there is sufficient priming. The minimum possible starting-temperature is, however, probably 30 or 40 deg. below the minimum temperature at which the fuel exerts a pressure sufficient to give a combustible mixture, because of the heating effect of the compression stroke before the ignition of the mixture of fuel and air is accomplished.

The vapor-pressure curves for the partly condensed mixtures give an indication of what can be accomplished as to starting in cold weather with various amounts of choking.

Table 2 compares the three fuels investigated in their more important characteristics.

It is hoped to continue this work further by determining the foregoing type of data for various types of blended fuels, naphthene base fuels, etc.

STARTING ON ALCOHOL

AT first sight some of the statements made in this article, taken from *The Motor* (London), appear to contradict known facts regarding vaporization and ignition of alcohol. Adiabatic compression always increases the vaporization and lowers the ignition temperatures of this substance and seems to favor easy starting. On the other hand, isothermal compression or compression at a constant temperature, *decreases* vaporization very decidedly. Compression at the ordinary speed of cranking is certainly far from adiabatic and may very possibly tend to retard rather than to promote evaporation. In any case, a reduction of pressure in the intake-manifold promotes evaporation.

It is interesting to note that the method finally recommended for starting with alcohol does not differ at all from the practice that has been developed in the United States for starting on the grades of gasoline marketed here. Apparently the British engineers have not had so much experience with low-grade fuels.

THIS Australian Alcohol Fuel Committee, while admitting that big problems remain to be solved in respect of the production and denaturation of power alcohol, has taken a step in the right direction by successfully tackling the problem of starting, from the cold, engines of normal design using alcohol alone as a fuel. Hitherto the general impression has been that, when this fuel is used without the admixture of ether or some other volatile substance, the use of a preheating device or the starting and warming-up of the engine on some other fuel is necessary when starting from dead cold.

Low Compressions

It is, of course, known that the use of alcohol favors the use of very high compressions, as giving better efficiency. Experiments have therefore tended in the direction of increased compressions, but it was observed that, though engines using alcohol would not start from the cold, the unexploded charge issuing from the exhaust could be easily ignited. Consequently the effect of reducing instead of increasing the compression was tried in an engine with an adjustable connecting-rod. The experiments started with compression at 60 lb. per sq. in., in which circumstances the engine gave no sign of starting from the cold. The cylinder was primed with fuel and the compression gradually reduced, attempts to start up being made at each stage. The first signs of an explosion occurred at a compression of 43 lb. At 34 lb. the engine fired regularly, and the best results were obtained between 35- and 25-lb. compression.

Subsequently it was found that the best way of reducing the compression was by controlling the admission of air. A large number of experiments were made. In a typical instance the engine of a 25-hp. Vauxhall car was started by placing a leather disc over the air-intake on the White and Poppe carbureter, admitting a little methylated spirit through the priming-cocks, and then cranking.

An extreme case of a successful experiment was that of a single-cylinder engine that started from the cold on alcohol after being packed in ice. Another engine was started regularly from the cold on 70 consecutive mornings at the first attempt without a single failure, the atmospheric temperature being sometimes as low as 9 deg. cent. (48 deg. fahr.).

Requirements for Using Pure Alcohol

Similar successes have been achieved with various types of engine, air-cooled and water-cooled, four-cycle and two-cycle. The conclusions reached are that the greatest ease of starting from the cold is secured under the following conditions:

(1) The throttle must be a good fit, but not entirely airtight
(2) The extra-air supply must be completely shut off
(3) The engine should be primed with a little alcohol fuel
(4) The crankshaft should be turned slowly to distribute the priming charge

Subject to these preliminaries, it is found that, by rotating the starting-handle at a fair rate, the engine picks up with certainty on the third or fourth compression-stroke.

A Survey of Oxyacetylene Welding

By Lorn Campbell, Jr.[1]

Minneapolis Section Paper

THE author discusses oxyacetylene welding as a factor of efficiency in manufacturing and states three reasons why rivets are being replaced by welds. Recommended practice with special reference to welding mild steel with the oxyacetylene flame is outlined and commented upon, the importance of the human element as a factor in successful welding being emphasized, as well as the necessity of drawing a much finer line than that of the neutral flame, necessary in welding most metals, when welding steel.

Steel-welding apparatus is described and commented upon and the subject of filler-rods considered. In testing welds it is necessary to break the weld so that the interior can be inspected for penetration, adhesion and oxidation.

LEADING economists inform us that henceforth the most successful manufacturing enterprises will be the ones operating along the most efficient lines. The wide-awake engineer will give due consideration therefore to the process of welding. Manufacturers of steel products, such as the various types of barrels, tanks and pressure vessels, should pay particular attention to their design so as to turn out the strongest and most efficient product at a low cost.

Rivets are being replaced rapidly by the weld. The three reasons this should be done are that (*a*) by securing a permanent seam that will not leak a better product can be obtained that will withstand more abuse, (*b*) the cost is reduced greatly and (*c*) if necessary repairs can be made readily. If a seam along a line of rivets opens, it is very difficult to make repairs under ordinary conditions, but if a crack is found in a welded vessel, it can be welded again in a very short time. There are many other reasons why tank manufacturers should use the welding torch in preference to rivets. One of the most important is the fact that fittings of almost any nature can be attached in practically all positions with ease, allowing a much greater latitude in design and construction. Steel castings can be fused to cold-rolled shafting or other stock. Automobile or tractor frames and all forms of structural iron need have no limit as to design, because the various parts can be fused together at any desired angle. Fuel-tank, fender, pressed-steel wheel, rim, pulley and other problems confront most automotive engineers. Perhaps, in some instances, there are other means of joining members even better than oxyacetylene welding, but it can be stated with safety that this process covers a very wide and elastic range of applications.

The oxyacetylene welding process emphatically has not reached its height. While the present applications seem unlimited, there remain many problems that will tend to broaden the field when they are solved. Cast iron and aluminum are metals that are fused easily. In some instances the former may come out with a few hard spots or blowholes, but these nearly always can be traced to lack of heat. With aluminum, the heat conductivity of the metal and its expansion and contraction are subjects that may require study. Malleable iron presents a problem all its own; having been annealed, the question is how a part of the casting can be melted and again restored to an annealed state. At present a tough bronze is used to bond malleable iron; thus the anneal is not destroyed and a union results that usually is amply strong, provided a slight reinforcement is possible. Brass presents no difficulty if the correct filler-rod and flame are employed. This applies to copper and steel when they are cast, but when they are drawn or rolled the heat causes the molecules to expand and changes the nature of the metal surrounding the weld. A practical method of restoring this metal to its original condition should warrant consideration.

Recommended Practice

Since calling particular attention to certain necessary precautions that pertain to the welding of special metals results in the making of better and sounder welds, it is not amiss to dwell upon the welding of mild steel. Although steel is a very commonly used metal and one of the first to be welded, the fact remains that it is the most difficult to fuse successfully. Many welders think of steel as steel and that, if one kind of steel gives certain results under the influence of the welding flame, all steel will act in a like manner; but this is not the case. Separating the principal factors into the different classifications, in the order of their importance, first comes the human element, next the apparatus and then the filler-rods. More will depend upon the human element than upon anything else, for the welding plant itself will not do the welding, any more than a blacksmith's forge will produce chains, chisels, tongs or any other products; it is the "know-how" of the operator that produces results. Anyone might purchase a doctor's equipment, but this would not make him a doctor, because much schooling and experience are necessary; so it is with the welder, whom we might term a metal doctor.

In welding mild tank-steel there is much for the operator to take into consideration. The carbon content of the metal, the surface oxide or mill scale, the size of the welding tip, the adjustment of the flame and the size of the filler-rod all exert a direct influence upon the weld. The carbon content varies from 0.15 to 0.25 per cent in steel of this nature, and a tensile-strength of 52,000 to 60,000 lb. per sq. in. is required usually. As the amount of carbon is increased the welding naturally is rendered more difficult.

As steel in a molten state is very susceptible to changes, it should be held in that condition no longer than is absolutely necessary. Nitrogen and oxygen from the air will be absorbed by the melted metal. This reaction is increased greatly when the metal is overheated by using too large a tip. Usually this fault is found where an effort is being made to attain speed in welding. As the metal cools and contracts there is a natural tendency on the part of these gases to free themselves and small blowholes or pinholes will make their appearance. The metal is liable to be hard and brittle. If rewelding be found necessary, the metal will be subjected to the same treatment again and an added weakness is to be expected.

The correct size of tip depends upon the operator, for very few men obtain the same results even if the material and equipment are the same. Taking two welders, each working on test pieces cut from the same plate, the same

[1]Engineer, United States Welding Co., Minneapolis.

torch and tip being used, and gases from the same containers and the same grade of filler-rods being employed, we find that one specimen has about 50 per cent more ductility than the other in the vicinity of the weld. This confirms the importance of the human element. In accounting for this difference we examined the broken welds and found that the welds themselves had a flaky grain with all the characteristics of a casting, although not as uniformly, whereas the pieces that were welded were of rolled stock with a very fine close grain. At an intermediate space adjacent to the welds, the intense heat had caused the molecules of the original stock to separate and the grain became coarser. It is evident that a weld is a casting at best and that the longer the metal is kept in a heated condition the greater the effect mentioned will be, within certain limits. We can assume that one of the welds cited required a longer time to execute than the other. It is not therefore desirable under ordinary conditions to use a larger tip than necessary, but when a steel weld is made too rapidly, the grain limits will be very marked and narrow, in addition to the likelihood of the penetration not being thorough, indicating a weld with little ductility and one apt to crack after being placed in use. To obtain the best results these factors should be pointed out to the welders and each choose the size of tip that can be manipulated to the best advantage.

In welding most metals it seems sufficient to have what is termed a neutral flame, but in steel welding a much finer limit must be drawn. A common cause of faulty steel welds is the wrong kind of neutral flame. Neutral flames are sometimes soft, but generally they are very harsh. It is next to impossible to make a thoroughly satisfactory steel weld with a harsh flame. While it may be all right for building-up worn spots and the like, it has no place in working with the lighter sheet-metals. If it is used in the latter class of work, there will be not only a tendency to blow the molten metal away from the weld, but an overheating, which is indicated by the excessive sparks given off, is certain to occur. It is absolutely necessary that a soft neutral flame be used when making any kind of a steel weld; and, the softer the flame is, the easier it will be to effect a perfect fusion. A soft flame will not blow or overheat the metal. With a low-carbon steel, hardly any sparks should appear while a weld is being made; this is a criterion of whether an operator really knows his business. If sparks are in evidence, there are impurities in the piece being welded or the metal is being burned.

Steel Welding Apparatus

The apparatus plays an important part in steel welding. While there are many different makes of apparatus on the market today and all seem to function fairly well on most metals, there are few that give the adjustment required for steel welding. There should be a regulator on each line, one to control the acetylene and the other the oxygen. These regulators must be constructed so as to maintain an unvarying pressure in order that there will be no change in the welding flame while it is in operation. The welding torch should be designed to give a slow uniform delivery, at the tip, of the gases that have been thoroughly mixed. This will permit complete combustion of the gases. No unburned gases can enter the weld then, and the preheating flame of hydrogen that envelops the neutral flame will exclude the air and protect the weld so that it will be possible to convey a small clear pool of molten steel along the seam. The desired results can be obtained with and greater efficiency will follow the use of the equipment described.

Some welding torches employ the injector or semi-injector principle in which the oxygen as it is forced through a very fine opening under a rather high pressure is relied upon to draw in the acetylene under a lower pressure. These torches may be satisfactory on some classes of work, but they are not recommended for steel work. In nearly every instance a slightly oxidizing flame can be noticed with such torches which, instead of improving after they have been in service for a time, become worse on account of small particles of dirt lodging in the fine oxygen passages. This necessitates still higher pressures on the oxygen line to force the needed volume of gas through. Cleaning this type of torch occasionally will help to some extent in keeping the oxygen pressure down as low as possible. It is well to remember, however, that excess oxygen is the welder's worst enemy; hence, the lower this pressure can be kept, the better it is for the weld and the welder.

Filler-Rods

In choosing filler-rods freedom from impurities and a low carbon-content are the main considerations. The size has a direct relation to the flame size. If the rod is too small it will burn usually; if it is too large, it will not fuse with the metal that is being welded and probably will have a tendency to stick. When introducing the filler-rod, the flame should come into direct contact with it as little as possible. It is desirable to melt the end of the filler-rod in the molten metal rather than by the flame, as there is less chance of changing its character.

When making ripple welds on pressure vessels, it is necessary for the operator to hold the tip at the correct angle and have the flame adjusted so that a small pool of clean melted metal will be carried along the seam. Constant watching is required to see that each side of the weld is thoroughly fused; penetration must be complete and the filler-rod added to give slight reinforcement, so that the resulting weld will be about three times as wide as the metal is thick.

Focusing attention on the human element to see what steps can be taken to insure the greatest efficiency, by testing welds periodically and publishing the results an esprit de corps can be built up among the welders in a large shop that will encourage all concerned and certainly assist in producing better results. In testing it is necessary to break the weld so that the interior can be inspected for penetration, adhesion and oxidation, because a weld must be more than skin deep and the nature of the interior seldom can be determined from outside appearances.

THE DISCUSSION

C. S. Moody:—During the war our welders complained of having difficulty with their filler-rods in that the metal came off in chunks. They did not seem to be able to produce good work. Examining a good and a poor filler-rod for test, I found that one was high and the other low in carbon, the good one being low in carbon. After some difficulty we obtained the low-carbon filler-rods we wanted, but had trouble again.

Lorn Campbell, Jr.:—If the filler-rod metal came off in chunks, this was no doubt due to impurities in the rods.

Mr. Moody:—We made an investigation and determined that the condition of the carbon in the rod has a good deal to do with the matter; by heat-treatment we made good welding rods out of the higher-carbon poor material. Further, we made good welding rods out of poor low-carbon or practically carbonless rod by suitable

heat-treating. We salvaged a great quantity of material in this way.

MR. CAMPBELL:—Before the war practically all of our welding rods were imported. They were called Norway or Swedish rods. It is very common now to have people call for Norway iron in the welding industry. During the war none was supplied. The American product has been refined to such an extent that it approaches the Swedish iron very closely, but it does not equal it.

Steel welding is very difficult; very few welders can weld steel thoroughly. The best way to test a welder's ability is to give him two pieces of plate about ½ in. thick and say 4 in. wide, have him make a fusion from one side and then break it on the anvil through the weld in any direction. It is immaterial whether one side or the other is broken. Invariably, it will be found that the weld has penetrated only one-half of the way through. It is difficult to say whether that is due to defective vision or what causes it. Some welders will swear that they have their flame in contact with the metal when in reality they are holding it about 1 in. away. The steel or the metal may increase in size as we know it does when it is heated to the melting point, and they may think they are completely through when in reality they are only one-half of the way. Much depends upon filler-rods. They are the cheapest part of the weld. With a difference of a few cents in the cost of filler-rods one is almost warranted in purchasing the finest filler-rods possible.

A MEMBER:—I have never heard anyone else make a distinction between neutral flames. How do you define a soft neutral flame?

MR. CAMPBELL:—Neutral flame is a term used in welding. It refers to theoretically equal parts of oxygen and acetylene. We find it necessary to add one part of oxygen to one of acetylene, the gases combining while passing through the pipe-lines. The additional oxygen is taken from the air. Most torches require slightly more oxygen than acetylene. As manufacturers, we are called upon frequently to specify the gas consumption of various sizes of tips, so that costs can be computed accurately. The different sizes are distinguished numerically. A typical question is, "How much gas does a No. 6 tip consume in a given period?" We can make that tip consume almost any amount of gas desired, with a short or with a long flame. In the welding of most metals it does not matter much whether a long or a short flame is used but in steel welding careful adjustment of the flame is necessary in order not to injure the steel when it is melted. If the flame has a hissing sound it is harsh, but it is still a neutral flame. In steel welding we need a soft neutral flame of ordinary length. If that is not giving enough heat, a larger size of tip must be used and the length of the flame cut down. In all cases the flame should be soft and give no sparks when working on steel. Sparks mean that there is burning metal or that there are a great many impurities. A good welder will recognize this condition instantly.

A MEMBER:—Do I understand correctly that a soft flame is caused by reducing the pressure and increasing the size of the tip?

MR. CAMPBELL:—Yes; the heat of the flame is the same but the flame length varies.

A MEMBER:—Is it more difficult to weld steel from one side?

MR. CAMPBELL:—It is desirable to do so.

A MEMBER:—For what reason?

MR. CAMPBELL:—The longer the steel is subjected to the action of the flame, the greater is the chance of burning it. If the weld is made from one side and it is done thoroughly, time and gas are saved and a better fusion is made.

A MEMBER:—It has been my practice to weld on both sides. I learned to do this myself. I thought there was less gas used because of the smaller cross-section to be filled in.

MR. CAMPELL:—Welding a ½-in. steel plate from one side and reinforcing, all in one operation, is perfectly possible and it is being done continually. There is no need to go over a steel weld a second time; in fact, a steel weld should be fused thoroughly the first time. It is well, however, in such cases to find the places where there will be strains and to anneal the ends of the pieces first, as that aids materially, and then bring them to a red heat slowly with some form of preheating apparatus before bringing the welding torch into use and actually commencing the welding operation.

MR. MOODY:—What are the relative merits and demerits of oxyacetylene and oxyhydrogen methods of welding?

MR. CAMPBELL:—A comparison is hardly possible. Oxyhydrogen welding is limited to thinner materials; oxyacetylene welding can be used with both thin and thick metals. We have executed welding jobs within the last year in which we have added over 600 lb. of cast-iron filler-rods in making large welds. The oxyhydrogen flame has a much lower temperature and is used extensively for cutting. It is very valuable because it makes a smoother cut, will cut faster and is much superior to the oxyacetylene flame for that purpose, in many instances.

MR. MOODY:—In places where it can be used, does it not make a more perfect weld than the oxyacetylene flame? With the oxyacetylene flame nitrogen is put into the weld, but that is not done by the oxyhydrogen flame. The nitrates introduced when welding with oxyacetylene form a needle-like structure that causes brittleness. The hydrogen flame is used on metals that become oxidized readily.

MR. CAMPBELL:—The oxyhydrogen flame is used in handling aluminum ware and in one or two instances in welding very thin steel-plate, but otherwise it is not used very much. The amount of nitrogen entering an oxyacetylene weld is extremely small and generally is disregarded.

D. W. ONAN:—What method is used to keep a thin plate from buckling?

MR. CAMPBELL:—It is usually clamped with angle-irons.

MR. ONAN:—Is there no other practical way of guarding against this distortion?

MR. CAMPBELL:—No; except that an allowance is made for the buckling. In making a steel weld along a seam, ordinarily ¼ in. per ft. should be left to allow for contraction; otherwise there will be overlapping and buckling.

Aberdeen Proving Ground Visit

PROBABLY not since the days of the war have the members of the Society experienced the sensations that were theirs on their visit to Aberdeen Proving Ground on Oct. 7, by invitation of General C. C. Williams, chief of Ordnance. There was a strongly reminiscent feeling of the time when nothing mattered but the production of the tools for making war and when anything less than 24 hr. a day on the job was considered in the light of a vacation.

On arrival, the visitors, including over 200 Society members, were met at the Aberdeen Station by the Proving Ground train and taken at once to the range where the 16-in. 50-caliber gun was fired. This gun, having a range of over 30 miles, can outshoot any gun on any ship in any navy. After a group photograph had been taken of the visitors, the program was continued by the firing of various smaller-caliber guns and by an inspection of a number of types of aircraft and of American and foreign aerial bombs, including the monster 2-ton bomb recently developed. Bombs were later dropped from airplanes both into water and on land. One of the most interesting demonstrations was the use against small free balloons of tracer ammunition from machine-guns, by which it was possible to visually follow the flight of the bullets from the gun to the target.

In the afternoon an automotive apparatus circus was of particular interest to the members of the Society since it presented a number of types of motor-driven vehicle, including large and small tanks and numerous caterpillar tractors and gun-mounts, one of which displayed remarkable speed and flexibility of control. An inspection was made of mobile ordnance repair-shops, and in the evening a demonstration was given of a newly developed flashless powder that will make it much more difficult to ascertain the location of guns by their flash.

The thanks of the Society are due to the Ordnance officers who planned and carried out the remarkably comprehensive and exceedingly interesting program with much precision. Each demonstration was carefully described immediately before it actually took place. There was scarcely a moment throughout the entire day unfilled with some event of interest.

Not the least diverting part of the visit to Aberdeen was the journey by motor-bus of over 20 members of the Metropolitan Section who left New York City on Thursday morning and arrived at seven in the evening at Wilmington, Del., where they spent the night, reaching the Proving Ground after a 2-hr. run on Friday morning. While the cost to the members who traveled by this bus was limited to their hotel bills, through the courtesy of the International Motor Co. in providing the bus, an analysis of the actual cost of transportation, including the items of gasoline, oil, depreciation and driver's wages

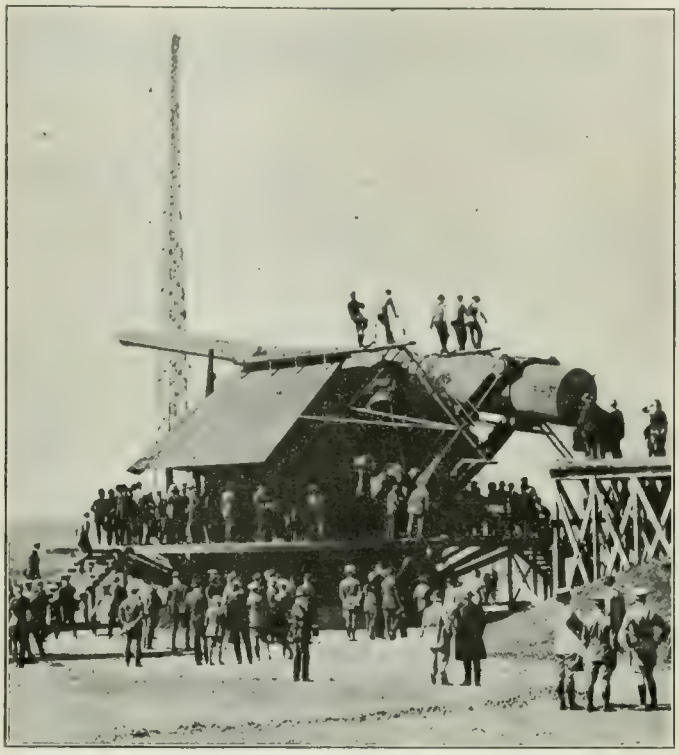


Photo by International

MEMBERS OF THE SOCIETY INSPECTING THE NEW 16-IN. 50-CALIBER GUN THAT IS MOUNTED ON A DISAPPEARING CARRIAGE AND HURLS A 2400-LB. PROJECTILE APPROXIMATELY 22 MILES

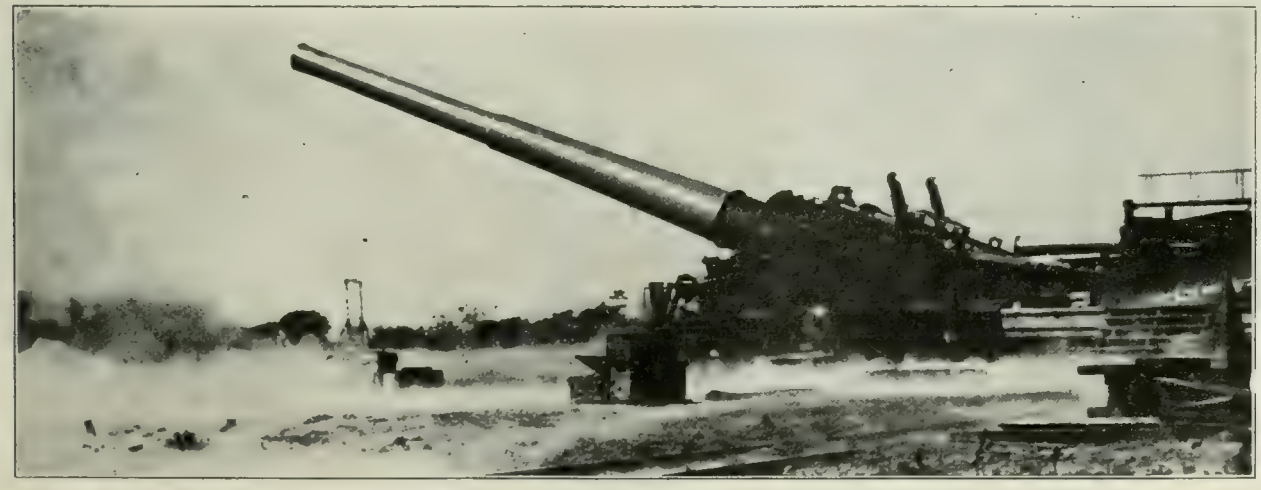


Photo by International

A NEW 16-IN. GUN ON A RAILROAD MOUNT BEING FIRED

and expenses, showed a figure of slightly over 1 cent per passenger-mile with the bus fully loaded. This is in marked contrast to the present rate of railroad transportation, which is in the neighborhood of 4 cents per passenger-mile, and illustrates forcefully the practicability and economy of using buses for pleasure touring when speed of travel is not essential. It is perhaps not too much to say that the term "pleasure car" that has been so erroneously applied to the passenger car may well be used in the near future to describe a type of vehicle which can carry a moderately large party of people over good highways, past attractive scenery, in comfort, cleanliness and at a cost of possibly one-third of the railroad fare.

CONVERTING COAL INTO GAS

IT is about 70 years since James Young first established the Scotch shale industry. The material he used, and from which the best results have been obtained, was known as Torbane Hill shale, the supplies of which have been exhausted for some time. As a matter of fact, this particular mineral was not a true shale, but actually a cannel coal. The mineral when distilled yielded about 125 gal. of oil per ton, but the shales distilled since its exhaustion, which are obtained chiefly in Midlothian and Llinlithgow, are not so rich in oil-content. A large quantity of shale exists in different localities in Great Britain, some yielding on the average about 50 gal. to the ton; but, unfortunately, the oil obtained has a high percentage of sulphur in its composition, and so is practically useless. So far, this oil cannot be purified by any of the usual methods.

Coal Tar a Source of Oil

A source from which large quantities of oil are forthcoming is ordinary coal tar, which, as obtained at the ordinary gas works from the carbonization of bituminous coal, is an extremely complex mixture of carbon, hydrogen, nitrogen and other elements. When tar is subjected to distillation, the light hydrocarbons are the first to come over, followed by heavy oils and tar oils, all of which are in great demand. It seems probable that coal will, in the future, be regarded as a great source of oil supply. The time is coming when we shall be unable to afford the transport facilities for moving coal on congested railroads. We shall not be able to afford or obtain the labor to perform the arduous work of handling solid fuel and clearing and removing ashes from furnaces and grates. Solid fuel must gradually die out for marine work, oil fuel taking its place, and locomotives also will be fired with liquid fuel, in which term is included the colloidal mixtures of solid and liquid fuels. At present it seems impossible to think of liquid fuel as a general means of supplying heat and power, nor can the generation and transmission of power by electrical means be considered as meeting the requirements for the provision of heat for general and industrial needs. Its average heat-efficiency today does not equal 10 per cent, and although it is certain that this figure can be improved upon it will certainly be many years before it reaches as high as even 20 per cent, and from every point of view it is unthinkable to transmit heat by a method in which from 80 to 90 per cent of the actual heat value is lost.

Advantage of Gas Producer

The one other source of transmitting heat from the coal mine, the source of fuel supply, to the user of gas, is in converting coal at the mine into liquid and gaseous fuel. Liquid fuel will be recognized as the medium for providing energy for all transport by land, sea and air, with the exception of electrical transport for congested areas, while gaseous fuel will be used direct for most heating purposes and for the generation of electricity by either internal-combustion or steam-driven engines.

There are several advantages in the use of gas producers, chief of which are that a poor quality of fuel can be used with good results; that the capital and operating costs of the plant are low and that high returns can be made by the recovery of the ammonia formed in them from the nitrogen in the coal. It appears, however, that the tar oils obtained from their working are not valuable, the condition in which they come from the plant is such that it is difficult to work them up, and in the opinion of tar distillers the final products compare far from favorably with those obtained from other methods of effecting the destructive distillation of coal. Now that all qualities of fuel have increased so greatly in price, and low-grade fuels have risen in cost in a far greater proportion than have other and better qualities, there is not the same saving that there is in the use of producers.

The Principle of Total Gasification

Low-temperature carbonization, on the face of it, should be a simple process. Many of the difficulties of high-temperature working are absent, but of course, there are others incidental to the process. Coking coal at low temperature swells and becomes gummy, and it is not the easiest of matters to get the sticky friable mass to leave the vessel. Still, on the assumption that the difficulties can be overcome and the process worked satisfactorily, the resultant tar oils are high in quality and quantity. There is, however, a residue of solid fuel, though producers convert it satisfactorily into gas to enable a further proportion of the ammonia to be recovered. The principle of total gasification is the partial carbonization of coal in a vertical retort superposed on a water-gas generator, the retort being heated externally by the products of combustion of the producer during the "blow" period, and internally by passing the water-gas made up through the charge in the retort. The plants are built in duplicate, and the gaseous products are passed up one plant and down the other for the purpose of fixing all the hydrocarbons and retaining them as gas. The great detraction from the national value of the process is that it yields no tar oil, while by fixing the gas, ammonia as well as the tar, is destroyed.

For a system that will meet the demand for liquid and gaseous fuels, for practically all purposes, the total gasification of coal is essential, preferably in one vessel. The plant must be economical in first cost and low in labor charges, but, above all, the maximum amount of the volatiles in the coal must be recovered in a liquid form, being distilled over in such a manner and at such a temperature that a minimum of "cracking" takes place. The gas should be stripped of all saturated hydrocarbons, and special care should be taken to preserve all ammonia. The plant should be designed to work with any coal of a far from uniform character over short periods.—*Oil News.*

MOTORIZED STOCK FARM

THE most completely motorized farm that we have found in the corn belt is located in Lake county, Illinois. It is not what would be considered a typical corn-belt farm; rather it is a live-stock farm, for all the crops grown are fed on the farm. As this farm comprises 3500 acres it is evident that a large amount of live-stock is kept. Approximately 2100 acres is in crops, and 1000 acres in woods and permanent pasture.

In spite of the fact that the horse is fully appreciated he has had to yield a large part of his domain on this farm to the tractor, truck and automobile. The horse is not entirely displaced; far from that, for the manager believes that it is not practicable to dispense with his services entirely; but the equine motor has been oriented into his place judged by the rigid standard of operating expenses. The tractor is used on this farm because for certain work the operating expenses are lower, and in his sphere the horse is used for the same reason. There may be other farms in the corn belt where as many crop-acres are grown per horse as on Hawthorn Farm, but we have never visited a farm where as many and varied operations were performed with the tractor nor where the tractor was used as many hours per year.

This year the crops grown consist of 700 acres of small grains, 677 acres of corn and 703 acres of hay. The field work starts about the middle of March. As soon as the ground is in condition the seeding of the small grain starts. The outfit consists of four tractors each pulling a 10-ft. double disc, two tractors each pulling two 8-ft. grain drills, two motor cultivators each pulling a 25-ft. spike-toothed harrow. If the ground has been fall-plowed it is double-disced once, but if the small grain is to be seeded on corn ground which has not been plowed it is double-disced twice. The ground is first disced, then seeded and crossed with the spike-toothed harrow. This crossing is done to break up the corn-stalks more effectively. The grain is hauled to the field with horses. To reduce the number of stops when seeding the boxes on the drills have been enlarged to twice the normal size.

Two men are required on each drilling outfit, one to drive the tractor and the other to watch the drills. Markers are used to guide the driver of the tractor on the drilling outfit. Careful checks showed that where horse-drawn drills were used it was not unusual to find that as much as 5 per cent of the area had been missed. With the tractor this skipping has been practically eliminated. In the past four years seeding operations have not been delayed because the tractor was being used nor have any ill effects from packing been observed. In fact this year the grain was taller in the tracks of the tractor.

The next operation is corn-planting. The corn ground is all fall-plowed. It is double-disced once with the tractor and harrowed and planked with the horses. Planting is done with a four-row machine operated by one wire and drawn by the motor cultivator. This planting outfit was made by an ingenious combination of two two-row planters. The checking is not as accurate as could be wished but is as good as has previously been done with the horse planters. This outfit was experimented with last year and used to plant the entire crop this year. The manager believes that its work can be improved in the future. The corn is harrowed before it comes up. Sometimes this harrowing is done with the motor cultivators, sometimes with horses, and again with both depending upon the developments in other farm work.

The corn is cultivated an average of six times. Three motor cultivators do the work following the rows, and 11 single-row horse-drawn cultivators are used for crossing. The three motor cultivators cover as much ground as the 11 horse-drawn outfits, but the manager is not yet convinced that the motor cultivator can be used successfully in crossing. As cultivating is the determining factor in regard to the number of work-horses required, an effort is to be made to improve the checking of the corn so that the two-row motor cultivator can be used in cross cultivation.

The harvesting of the first crop of alfalfa starts before corn cultivation is finished. One tractor with three mowers behind it can cut 35 acres per day. Only one man is used on this outfit. The first crop of alfalfa is unusually heavy. In raking one tractor pulls two side-delivery rakes. For the second cutting one tractor pulls four of these rakes. The hay is gathered with hay-loaders. One tractor pulls two wagons and two loaders. The hay-fork is operated with a drum driven by a gas engine. The hauling from the field to the barn is done with tractors, each machine pulling a train of three wagons. The number of tractors used in hauling depends upon the distance.

This same system of hauling and equipment is used for hay, shock grain, manure and corn. When the management decided to concentrate the live-stock plants it was recognized that hauling would be a big problem. The solution decided upon was to pull a train of three wagons behind one tractor, thus enabling one man to move a large tonnage. This system has worked well. The method of assembling or breaking up a train is interesting. A team of horses is attached to a light two-wheeled truck. On the back of this truck there is a hook that can be attached quickly to the end of the stub tongue on the wagon. The same type of hook is used on the back of each wagon. When a wagon is loaded the snap team draws it up in a diagonal position with reference to the wagon it is to be hitched behind. The men who do this work have become so expert that the wagon can be stopped in such position that the connection is easily made. In breaking up a train the same equipment is used. The number of tractors used for hauling on any operation depends upon the length of the haul.

In some seasons the second crop of alfalfa is ready to put up as soon as the first has been harvested. In any case harvesting starts before the haying is finished. Three outfits are put in the harvest field. There are two 15-27 tractors, each pulling two 8-ft.-binders, and a motor cultivator pushing one 8-ft.-binder. Each of the larger outfits is operated with two men. The motor-cultivator outfit is used for opening up the fields, cutting off the corners, etc. When not at these jobs it is used in regular cutting. The mechanical shocker has been tried but abandoned.

The threshing is done with a 40 x 64 machine. A shock loader pulled by a tractor is used for loading the grain in the field. The wagons are hauled to the thresher by the tractors, where the snap teams take them up to the self-feeder. No men are used on the straw stack. The grain is run into the wagon boxes and unloaded with an elevator. The shock loader, elevator and absence of men on the straw stack were innovations introduced this year. The shock loader eliminated the use of seven men, the grain elevator seven and the method of stacking the straw three. The manager stated that the saving on the labor bill will pay for the new equipment this year. In addition to this a tractor was released from the threshing work and set to plowing.

With the threshing out of the way the next operation is hauling manure. The wagons are loaded in the yard by five pitchers, drawn out with snap teams and coupled into trains. The tractors are used to draw these trains to the field. Here, the manure is transferred by a ditch-filler and tractor to spreaders, which are operated by horses. Three tractors hauling and one unloading kept four spreaders busy at a distance of 1 mile from the yard. If the haul is shorter fewer tractors are used; if longer, more.

Mechanical Manure-loader Needed

A mechanical manure-loader is much needed. When a successful one is secured one man will do the loading which now requires five. Some objections might be raised to this method, because the manure is handled twice, but this is more than offset by the time saved in hauling. Each wagon makes from two to three spreader loads, and the transfer is made with little loss of time. It averages about 2 min. per load. If it is possible to secure a loader the manure will be transferred from the yard to the field without being touched with a fork.

Silo-filling is carried on in accordance with the scale on

which other work is done. Two binders, each pulled by a tractor, are used to cut the corn. Elevators are attached to these binders. A tractor pulls the wagons alongside and the train is loaded. It requires 4 tractors and 12 wagons to get the corn from the field to silo, where it is run through a 15-in. filler operated by one of the big tractors. Over 200 tons of silage per day can be put up with this outfit.

With the silo-filling out of the way the chief interest centers on the fall plowing. There are about 1000 acres of this to be done. Each 15-27 tractor with a three-bottom plow can turn about 8 acres per day. The corn which is not put in the silo is picked by machinery in the field. A tractor is used to pull the picker, but as fall plowing is on at this time the corn is hauled to the crib with horses. The picker will gather 18 double wagon-box loads per day.

The tractors are used almost continuously from the middle of March until the middle of December. Very little time is lost on account of breakdowns. The manager estimated that the 15-27 tractors were used approximately 200 days per year.—E. A. White in *Farm Implement News.*

AUTOMOBILE BUILDING IN ENGLAND

MASS production is an expression constantly on the lips of English shop managers. This is understood to be an American phrase or, at least, an American principle, though I do not remember having heard the term used here. The idea is plain enough to understand. It is that of making the product in a sufficiently large mass to take advantage of the latest and most refined production methods for the sake of reducing the cost to the lowest possible figure. Some English automobile shops have been reorganized on this basis, and the most successful of them would produce an output that would be fairly appalling there if they were running full-time and full-force on the plans for which they were laid out. The output would not, of course, be appalling in America. It is said that the number of automobiles licensed in New York City alone exceeds the total of all the British Isles; and the field occupied by the medium or low-priced car here is taken care of there by the motorcycle with side-car, which is the ordinary man's means of conveyance.

Automobile builders in England have been looking to export trade as an outlet for the increased products of this "mass production." This offers no immediate prospect of success, however, owing to their inability to compete with American firms who are at a considerable advantage due to the greatly increased cost of material in England and to the fact that wages are, in many cases, now on a parity with those of America instead of being considerably below as in years past. This, added to the lower production capacity of the English workman, seems to make competition hopeless for the near future, at least in the markets of the world. The ability and willingness to do the highest grade of body-finishing and upholstering still survives in England to the extent that the stock cars of the best makers bear comparison with the finest product of the various factories in the United States producing custom-built bodies.

It seems that the great prizes in automobile production in England and France will go to the builder of the first-class car who is willing to study the following points carefully:

(1) Making such changes in the design as will facilitate the construction of the car without affecting its quality in any degree. A great improvement in this respect can be made in practically all high-grade cars

(2) Developing the ability to rough-machine the parts as rapidly as is done by the producers of the cheaper grades of car, while maintaining the fine finish and fitting in the final operation. This is difficult but possible

(3) Making a study of the possibilities of machine-finishing of parts where hand-work is now the rule. This applies to many surfaces where hand-work is of no advantage but costs more and is employed only out of deference to the tradition as to the excellence of hand-work in itself

(4) Making sure that the body-work and upholstering in general is done as finely as at present, and that the finished car will suffer in no degree whatever from the improvements in design and manufacture mentioned

(5) Specializing on one design of chassis. The builder who is willing to do this, can carry out all the previously mentioned points to a much more successful extent than the one who carries two or three designs. It should be possible to specialize without injuring the quality of the product in any way

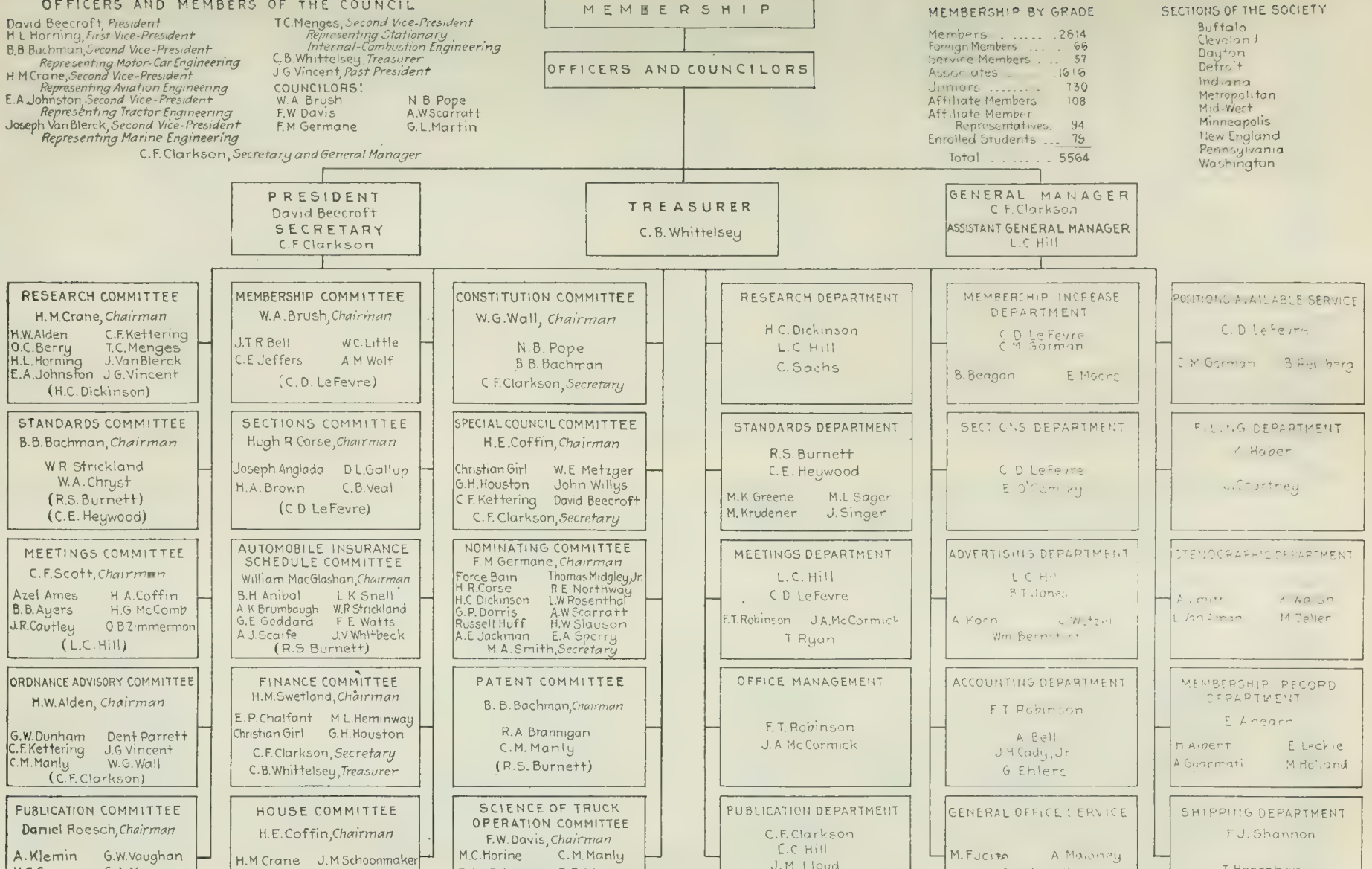
In America the producer who can build a car of fair quality in enormous quantity has an opportunity to make engineering skill reap the highest reward. In Europe the man who succeeds in solving the problem of design and construction for the very high-grade car, made in moderate quantities, will be the one reaping the largest financial reward.—R. E. Flanders in *Machinery.*

PATENTS

IN a year about 90,000 applications for United States patents are filed, of which about 35,000 come to issue. Counting the time of all the people involved as well as the money spent in fees and experiments, $100,000,000 per annum is a conservative estimate of the country's expenditure. And over 90 per cent of it is wasted.

Thousands of patents are procured for half-baked ideas doomed to failure. And strange as it may seem this phenomenon is not without its good results. It follows natural laws. Nature is prolific. Thousands of seeds are produced in order that a few may survive. Now and then the germ of a great idea is to be found in a half-baked invention. Most startlingly new ideas come from the rank outsiders anyway. Those entrenched in a particular field become cautious and conservative; they know the pitfalls, whereas an outsider is often the "fool who enters where angels fear to tread," and once in a while gets away with it.

It seems a pity that so much energy and money are wasted on inventions and patents when by the application of a few simple principles most of it could be saved. This would also result in giving inventions of true merit a better chance for a hearing, instead of overwhelming them by the general ill-repute of the others. The tantalizing part of it all is that there remains a tremendous field for invention as most of the arts are still in their infancy.—E. Scheyer in *American Machinist.*



STAFF AND INTERNAL COMMITTEE ORGANIZATION OF THE SOCIETY OF AUTOMOTIVE ENGINEERS, INC.

Radiators for Aircraft Engines[1]

By S. R. Parsons[2] and D. R. Harper, 3rd[3]

IN a technological paper bearing the above title, the National Bureau of Standards communicates much material which it hopes will prove of value to the automotive industry, as well as of interest to physicists and engineers generally. The paper describes the laboratory investigations relating to aircraft-engine radiators which were conducted by the bureau during the war and in the two years immediately succeeding it. Individual reports covering many phases of the subject have been published previously in the technical series of the National Advisory Committee for Aeronautics and in scientific and engineering journals. These reports, however, lack the systematic coordination, uniform terminology and unified mathematical treatment which would characterize a handbook on the subject. Moreover, later work threw much additional light upon matters not settled at the time of publication of the early reports. The present paper is a complete revision and recompilation of the material available.

The special investigations reported included development of the methods of measuring airflow in radiator tubes; experiments upon the effect of nature of surface upon airflow and upon heat dissipation from the surface of metal tubes to a high-velocity airstream; experiments to ascertain the degree of turbulence in the air-tubes of a radiator core; and mapping of temperature distribution, axially and transversely, in the air-tubes of radiator cores. In addition to recording these special investigations, the paper contains a full description of laboratory methods and instruments for those tests of radiator cores properly made in the laboratory, of both physical properties and geometrical characteristics such as size and shape of air-tubes and of water-tubes.

The work included laboratory measurements of cooling power, head-resistance and geometrical characteristics of over 100 types of radiator core. These data are tabulated in an appendix and the performance characteristics of 66 types of core are given in graphical form. The general conclusions from these measurements and from the special laboratory experiments already mentioned are incorporated in an exposition of the fundamental relations between the conditions under which a radiator operates, its characteristics of form and construction and the properties which describe its performance. This portion of the designer's field is by no means the whole, however, and the paper does not treat the important considerations of sturdiness, ease of construction and repair, cost, form of design imposed by the structure of the aircraft and the like.

Heat Dissipating Power of Cores

The heat-dissipating power of a given type of core construction was found to be specified completely when the mass rate of airflow is specified. It makes no difference whether a given mass rate is obtained by high velocity and low density or low velocity and high density, a relation which was studied in some detail because of its significance in respect to behavior of aircraft radiators at great altitudes of flight. The empirical relation

$$H = bM^n T$$

where H is heat dissipated per unit time per unit frontal area of core, M is mass of air per unit area per unit time through the air-tubes of the core and T is difference between the average temperature of the water in the radiator and the temperature of the air at entrance to the core, was found to hold for all ordinary types of core construction, b and n being constants pertaining to any particular core. The numerical value of n was usually in the neighborhood of 0.8, indicating that the relationship between heat dissipation and air-flow through the core of a radiator is not far from the relationship of direct proportionality, although too far to assume such a relation over any considerable range of air-flows.

A second equation for computing the cooling power of a core is

$$H = C_p MT\ (1 - e^{-\alpha x_1})$$

where H, M and T have the significance quoted in the preceding paragraph, e is the logarithmic base 2.718, C_p is specific heat of air at constant pressure, x_1 is the depth of the radiator core, a dimension parallel to air-flow, and α is a constant for a given core and given airflow through it. Since a chosen value for α permits no latitude in airflow or in changing core construction, the equation in this form is intended primarily for study of the effect upon cooling power of changing the depth of core. Giving due consideration to head resistance as a function of frontal area and depth, the formula permits computation of the optimum depth of radiator for given conditions. For very high-speed flight, it is advantageous to use cores much deeper than was the common practice in the early days of airplane development, 8 to 10 or 12 in. of depth being desirable for some types of the usual ¼ to ½-in. air-tube core in unobstructed positions.

The formula just quoted is not entirely empirical in its origin, but has a rational basis. The assumptions underlying it are plausible and it is not surprising to find that in applying it to results of measurements with almost all common types of core these results are represented very well. The parameter α is an abbreviation for pq/MC_p, where M and C_p have their former significance; p is total perimeter of the air-tubes in unit frontal area, provided the cooling surface is all direct surface, and an equivalent value for the cases where part is indirect cooling surface; q is the cooling coefficient between the metal and an airstream of velocity corresponding to M, namely, q is heat transferred per unit time per unit area of metal per degree temperature difference between the metal and the air flowing past it. The numerical values of q were found to agree very well with values computed from a formula given by Stanton and Lanchester,

$$q = \frac{C_p R_f}{V}$$

and by Lees,

$$R_f = \rho V^2 \left[0.0765 \left(\frac{\mu}{V\rho D} \right)^{0.35} + 0.0009 \right]$$

the comparison being made for radiator cores with smooth round and square and hexagonal air-tubes, nearly all direct cooling surface. The formulas given

[1] Abstract of an official publication of the Bureau of Standards, Washington; communicated with the permission of the Director of the Bureau of Standards.

[2] Assistant Professor of [illegible] University of Michigan, Ann Arbor, Mich.

[3] Physicist, Bureau of Standards, Washington.

were originally stated for long circular cylindrical tubes with smooth walls, C_p being specific heat of air at constant pressure, V the velocity of the air through the tube, ρ its density and μ its viscosity. R_f is the surface friction, or force per unit surface between the airstream and walls of the tube, and D is tube diameter.

The foregoing formulas can be combined into a single expression, making some reductions not given here in detail, so as to compute heat dissipation of a core from its dimensions. For the simple type of regular cellular cores, it seems highly probable that results will be reliable within 10 per cent.

$$H = MC_pT(1 - e^{-(\alpha x_1)})$$

$$\alpha x_1 = \frac{x_1}{r}\left[0.0471\left(\frac{a\mu}{rM}\right)^{0.35} + 0.0009\right].$$

where

H = heat dissipated, in units of power per unit frontal area of core
M = mass of air per unit time per unit frontal area
C_p = specific heat of air at constant pressure
T = temperature difference of the water and air entering the core

Any consistent set of units whatever can be used for the above four quantities, but care must be exercised to avoid any inconsistencies; that is, the heat units for H and C_p must match, and so must the mass units for M and C_p, the area unit for H and M, and the like.

One consistent set of units in English measure would be as follows:

H = British thermal units per second per square foot of frontal area
MC_p = Pounds per second per square foot, multiplied by the number of British thermal units per pound per degree fahrenheit
T = Degrees fahrenheit
x = Feet
r = Feet
a = A ratio, in any units such as square feet per square foot of frontal area, or, mass pounds per foot per second
M = Mass pounds per square foot per second

The same is true for the following sets of quantities, although the units for these need not be the same as the first set.

x_1 = depth of radiator core, in the same units as those of r
r = hydraulic radius of air-tube, the quotient of area divided by perimeter
M = mass of air per unit time per unit frontal area
μ = viscosity of air in a unit consistent with M and r
a = free area of core; the ratio of the total cross-section of the tubes to the frontal area. Because it is a ratio, it is independent of units

Laboratory Measurements

The laboratory measurements of heat-dissipating power were made with two sources of heat, steam and hot water. For superheated steam, the effective temperature is computed by weighting properly the heat derived in each stage, such as loss of superheat, condensation and the cooling of the water, according to the formula:

$$T_m = \frac{\left(T_c + \frac{S}{2}\right)C_pS + T_cL}{C_pS + L}$$

where T_m is mean effective temperature, T_c is temperature of condensation, S is superheat in degrees, L is latent heat of condensation, and C_p is the specific heat of superheated steam. The condensate was usually not cooled significantly below the temperature of condensation and the formula given above is in the simplified form resulting from neglecting such cooling. An intercomparison of test data on 10 cores using both superheated steam and hot water as sources of heat for the calorimetric measurements showed that no appreciable difference existed between the results obtained by the two methods. A series of measurements using water as the source of heat were made with the rate of waterflow varying over a wide range. As might be expected, a wide range of variation of heat dissipation occurred with change of rate of waterflow when the rates were extremely low, but at the rates of flow common in radiator use the effect was not significant. It seems safe to assume that heat dissipation for conditions all constant except rate of waterflow will attain a value within 5 per cent of the maximum which it will reach with any rate of flow, if the rate be as much as 3 gal. per min. per in. depth of core 1 ft. wide. This flow is well within the margin of circulation found in most aircraft cooling systems.

The effectiveness of indirect cooling surface, namely, cooling surface not backed by flowing water, is considered in detail and the mathematical relations are developed which describe its behavior. The effectiveness of indirect surface is defined as the ratio of its heat-dissipating power to that of an equal area of direct cooling surface all at the temperature of the edge of the indirect surface which has contact with the source of heat. For long narrow fins such as the indirect cooling surface found in a square cell or hexagonal cell construction, the effectiveness is

$$E = \frac{\tan hU}{U}$$

where U takes the form

$$U = b\sqrt{\frac{2q}{yk}}$$

in which b is the width of fin where good thermal contact occurs along one edge of the fin only, and is one-half the fin width where good thermal contact is made by both parallel edges. A good thermal contact means soldered or integral metal. Mere contact, unsoldered, of two pieces of metal is thermally a discontinuity. The fin thickness is y and the thermal conductivity k, the quantity q being the surface heat-dissipation coefficient in units consistent with k and the dimensions b and y. If K be expressed in British thermal units per minute per square foot per degree fahrenheit per foot, and b and y be each expressed in feet, then q must be British thermal units per minute per square foot of surface per degree fahrenheit temperature-difference between the metal and the air. For the combinations of values usually occurring in radiator practice, the effectiveness exceeds 70 per cent and commonly averages 85 to 95 per cent. The formula was applied to calculate optimum dimensions for fins under various conditions, the results being tabulated. The equations of thermal conduction are also used to compute a table of temperature-drop through water-tube walls of various thicknesses and materials.

Details on Miscellaneous Topics

A considerable amount of detail not suited to abstracting is to be found in short notes on such topics as effect of yaw on performance, slipstream mountings, wing radiators, shuttering, radiator requirements at altitude and methods of computing performance at altitude from test data obtained at ground level. A brief treat-

ment is included of the subjects of partially streamlined casings to enclose a radiator, and of nose mounting.

From the viewpoint of an airplane designer it is desirable to specify radiator performance in terms of flying speed of the plane. In general, this cannot be done directly because too many factors are involved in the relation between flying speed and the airflow through the radiator core. It becomes necessary, therefore, for describing characteristics of the radiator, to adopt airflow through the core as the prime variable, there being no other quantity or entity available for the purpose. The ease or difficulty of applying such a description of performance to plane design rests then with the difficulty in estimating the probable airflow through the core for given flying speed. For a radiator mounted in an unobstructed position, the difficulties are inappreciable, the estimation process is replaceable by actual measurement and the results are obtainable with satisfactory accuracy. For a nose mounting, or other obstructed position, too many factors enter into the determination of the airflow to make generalizations possible. Consequently, without any intervening step, the authors are unable to include in the paper material of direct application, for the nose radiator, a mounting which is today probably the most common in American practice. The designer who is interested in such a mounting must first secure a measurement or estimate of the airflow to be expected in the core of his radiator, taking into account the size and shape of fuselage, engine, propeller and all the objects which will determine this airflow; then, with such data in hand, he can apply all the results of this paper.

Radiator Performance in Terms of Flying Speed

The paper is carried one step beyond expressing radiator performance in terms of airflow through the core, and states the results of the measurement in terms of flying speed for a mounting in an unobstructed position. Comparative performance is stated in terms of figure of merit, which is the ratio of the power dissipated as heat to the power required to sustain the weight of the radiator and overcome its head-resistance in pushing it through the air. The relative figures of merit of two cores in an unobstructed position do not, of course, furnish an index of value in an obstructed position. The comparative behavior of various classes of core are discussed in some detail for the unobstructed position and it is shown that for this mounting and high speed of flight, the flat-plate-core construction has a figure of merit sufficiently above other types to deserve attention. Its chief disadvantage is inherent mechanical weakness, a feature of extreme importance in selecting a design for use, and the data presented should afford the designer definite information regarding the sacrifice in figure of merit which must be balanced against increased sturdiness, when choosing between types of core. For flying speeds of 60 to 200 m.p.h., it seems certain that an unobstructed radiator plus a streamlined nose to the fuselage offers a figure of merit so much above that of a nose radiator installation as to justify considerable effort toward overcoming the structural difficulties attendant upon such a mounting.

The measurements made on a very wide range of variety of cores indicate that vanes, holes in the air-tube walls, and all devices intended to increase turbulence in the air-tubes are detrimental to radiators in an unobstructed position, lowering the figure of merit for a given flying speed. The effect is to decrease the airflow more than is compensated for by the increased heat-dissipating power at a stated rate of airflow. On the other hand, in obstructed positions, where the airflow is determined more by the radiator surroundings than by its own core construction, the cores with turbulence devices may be advantageous. For regularly shaped cellular tubes, with straight walls parallel to the wind and with no vanes or holes, an empirical formula was developed which was found to express airflow through the core in terms of flying speed, with a surprising degree of accuracy:

$$m = a\left[1 - (10)^{-44r/x}\right]$$

where r is hydraulic radius of an air-tube, the quotient of cross-section divided by perimeter, and x is depth of the core or the length of an air tube, both these dimensions being measured in the same unit of length; a, being the free area of the core, is the ratio of the total cross-sectional area of the air-tubes in a given frontal area to that frontal area; m is the airflow constant, the fractional part of the airflow approaching the core which passes through it; hence, unity minus the fractional part deflected around the core. In a windstream of 5 lb. per sec. per unit area, a core of unit frontal area which transmitted 3 lb. of air per sec. and deflected the other 2 lb. around it, would have an airflow constant of 0.60. The presence of headers or water-boxes would modify the direct application of the formula to a radiator, since the formula is for a core alone, but with the exercise of suitable judgment in making an allowance for water-boxes and connection piping it should be possible, from the geometrical characteristics of a simple core, to compute with a satisfactory degree of accuracy the airflow which would correspond to any stated flying speed with the core in an unobstructed position.

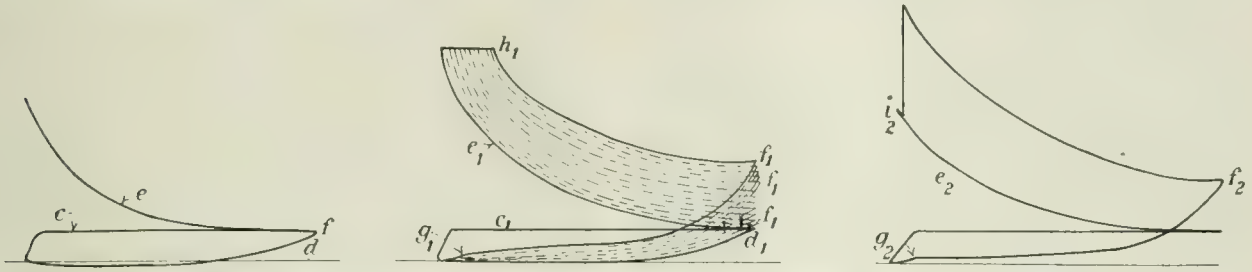
FARM TRACTOR PROSPECTS

WE learn from the census that there are in the United States 2,673,345 farms containing 100 acres or more. One may concede for the sake of argument that tractors cannot be used economically on farms of smaller size, although there has been considerable testimony given by farmers themselves showing that tractors have been and are being used to good advantage on farms having an area of less than 100 acres.

What percentage of these farms has been supplied with tractors? The census bureau tells us that there were 246,139 tractors on farms at the end of 1919. The farm equipment production and sales statistics of the Department of Agriculture are to the effect that 162,988 tractors were sold to dealers in 1920. Not all of these were sold to farmers in that year, but many of them have been sold this year. The census figures plus the 1920 sales figures give a total of 409,127 tractors that have passed through the wholesale trade. With these figures it is not unreasonable to say that approximately 400,000 tractors are in use on the farms of the United States at present. There are still 2,000,000 farms, the owners or operators of which are more or less definite prospects for the sale of tractors. The time is coming when at least 2,500,000 American farmers will have bought tractors, and thereafter they will replace worn-out machines as rapidly as necessary in order that the tractors may always be a part of their regular equipment.—*Farm Implement News.*

Correction for Summer Meeting Discussion

IN connection with the remarks of Elmer A. Sperry in the discussion of the paper by Messrs. Mead and Pierce, which was printed in the October issue of THE JOURNAL, some unfortunate errors occurred in reproducing the indicator-cards that were supplied. In preparing these illustrations for publication the cards were sketched from a series of photographic reproductions of the original indicator-cards and errors occurred in these sketches that make the illustrations entirely at variance with the statements made in the text. The illustrations of these cards have been corrected and are reproduced herewith with the following word of explanation from Mr. Sperry.



THREE INDICATOR CARDS OBTAINED FROM A 10 TO 1 COMPOUND AVIATION ENGINE USING AUTOIGNITION AND HEAVY FUEL-OIL

From Left to Right These Are a Cyclic Card without Fuel, a Card Showing the Range of Control from 10 Per Cent Overload to Idling by Regulating the Amount of Fuel Injected and a Card Showing a Straight Detonation

In the illustrations, the cyclic card at the left, after the engine is hot, rises and falls on practically a single line e.

The card in the center illustrates the method of engine control, in contrast with the usual throttling, by varying the fuel added after the compression of the air. Lines c_1 and e_1 will at once be recognized, but in this card various amounts of fuel are added which burn on the slow Diesel cycle, and as more fuel is added, the card becomes thicker. The outer line from h_1 to f_1 indicates 10 per cent overload and from this down to idling, which is represented by the line nearest e_1. The parallel lines terminating in the various points of transfer f_1 f_1 indicate intermediate powers.

The card at the right is given to illustrate the peculiar integrity of the detonation, which has been supposed to originate from introducing the fuel with considerable "lead." Instead of this, here is an instance where the compression e_2 has actually started back from its highest point, as it does in the card at the extreme left, before any fuel is introduced, whereupon the fuel introduced at the point i_2 with about a 12 deg. "lag" instantly detonates, as indicated by the vertical line, and the same cycle of operation is carried out through the point of transfer f_2 into the low-pressure cylinder to the point of final exhaust-valve opening g_2. The contrast between this card and the one in the center is marked by the expansion line proper starting much higher and farther to the left, representing an almost true Carnot cycle, piling the heat up at the beginning of the card and as far away from the exhaust-valve as possible.

EUROPEAN SCREW-THREAD PRACTICE

IT seems that the American form of screw-thread is practically unused in Continental Europe. From rough data gathered it appears that the use of the Whitworth thread varies from 50 per cent in France to 90 per cent in Germany. Hence, all of the metric countries are keenly interested in the screw-thread situation, particularly Austria, Germany, Holland, Sweden and Switzerland, which are, it is reported by Secretary Agnew of the American Engineering Standards Committee, anxious to agree on tolerances for the Whitworth form of thread. They take the view that they should follow the Anglo-Saxon countries in this work but are anxious that if the Americans and the British are to reach any agreement this should be done as soon as possible, for they consider the question a pressing one.

It is understood that at least the following have already adopted, or are practically certain to adopt three systems of screw threads as their standards: Austria, France, Germany, Holland, Italy, Sweden and Switzerland. The systems referred to are the Systeme Internationale, the Metric Fine Thread and the Whitworth. These are shown in Swiss Standards Nos. 12,005, 12,006 and 12,007. The Germans have definitely decided to abandon several less used metric systems, having not over three in final use. They are much interested in the number of threads per inch for the very large Whitworth screws. Their shipbuilding industry wants to continue the use of pitches coarser than 4 threads to the inch, on account of its use on British ships, but the other German industries want to limit the number of threads per inch to 4, as recommended in the report of the National Screw Thread Commission of the United States of America that was recently issued.

Germany, Holland, Sweden and Switzerland are definitely on the basis of the nut as the fundamental, according to Mr. Agnew. The Swiss have done extensive work on the subject of screw-thread tolerances, which has not been published. It deals exclusively with the Metric and the Whitworth threads.

The published Dutch standard on bolts has been withdrawn and is now being revised. The British have organized an Association of Bright Nut and Bolt Manufacturers and this has greatly stimulated their work on the general question of screw threads and on the details of nuts and bolts. The British Association stated that the Society of Automotive Engineers' thread is being used in England and that they are undertaking to determine the extent of its use.

THE GENERAL FARM TRACTOR

I PROPOSE to discuss the tractors for the general farmer raising the crops to which are devoted the greatest acreages. These will range from 8-16 to 16-32-hp. machines.

The farmer is interested particularly in the design of tractor that will enable him to do satisfactorily and economically as large a part as possible of the work he is now doing with work animals and portable engines.

Cultivating

The cultivation of the crops requires a number of special features in a tractor, such as ample clearance, light ground pressure, a gage that will enable the machine to get through the rows without injuring the crop and as short a turning radius as practicable.

The crops requiring plowing but no cultivation occupy less than one-half of the total area devoted to all crops. Inasmuch as by far the greater number of farms of the South are very largely if not entirely devoted to the raising of both corn and cotton, and both of these crops are raised as far north as climatic conditions permit, it seems safe to estimate that fully 75 per cent of all of the farmers in the United States raise some corn or cotton or other crops requiring cultivation. From the standpoint of the total acreage devoted to crops requiring cultivation, in view of the large number of farmers raising such crops and bearing in mind that the peak-load in hours of horse-labor on farms raising such crops comes during the cultivating season for those crops, it is most decidedly worthwhile to consider a tractor that can be used for cultivating such crops as well as do the other work now being done by work animals and portable engines.

The roots of a row of corn are almost at the surface at the stalk and have their greatest covering of earth midway between the rows. The same thing applies to cotton and other row crops. Single-row machines, that is, tractors able to pass between two rows and cultivate one row, or two half-rows as it is frequently put by the farmer, would necessarily have their wheels travel near the stalks. This would probably result in cutting many of the roots, thereby decreasing the nutriment furnished the stalks by the roots and thus reducing the yield. The soil is usually in a more or less plastic condition. The wheels passing over it will compact it, more or less, not only directly under the wheels but, because of the plastic condition of the soil, underneath the stalks where the effect cannot be overcome by the cultivating implements following the wheels.

A number of machines have been placed on the market which straddled two rows and cultivated three rows at one passage of the machine. These tractors, as a rule, were stable, and their wheels traveled midway between the rows. The wheels were large, or the machines were equipped with crawlers. Nearly all of the machines were large, requiring considerable space in which to turn around. This meant wider headlands or turn-rows, and an increase in unproductive land, or, if the rows were not widened, damaged crops in adjacent cuts. These machines were largely if not entirely of the three-wheeled type which meant less accurate steering. Covering two rows of various widths, it was necessary to make the outer wheels adjustable laterally. This reduced the rigidity of the machine and unquestionably increased the cost of maintenance. Furthermore, the work of changing the wheels was more or less arduous. However, by far the most objectionable feature was that the operator had to cultivate three rows at one passage of the machine. This is more work than one operator can attend to properly.

Tractors straddling one row and cultivating two rows at one passage of the machine are on the market. Their wheels are large and travel midway between the rows. They are stable. They are fairly light in weight and therefore do not compact the soil to a serious degree. Any compacting that may be done can readily be overcome by the cultivating implements following the wheels. Straddling but one row, the wheels do not have to be made adjustable laterally, for a gage can be arrived at that will be but a few inches from the center of the rows or middles in any of the width rows these crops are normally grown. Therefore the frame can be made rigid, as far as the gage is concerned. These tractors are about half as wide as the three-row type and usually much shorter. The tractors of this type are practically all of the two-wheeled type. They require the addition of a two-wheeled implement or carrier to make them complete and operative. This really makes them four-wheeled tractors and leads to considerable duplication, for each implement designed for this type of tractor must have two wheels. Because of the necessarily compact form of these tractors they are, I believe in every instance, provided with but one speed forward and one reverse. This requires the operator to consume as much time in doing light work as in doing heavy work. Having but one speed, should the tractor become stalled at that speed, it is necessary to call for assistance to get out.

It seems safe to conclude that the tractor for the general farmer will be designed to straddle one row while cultivating two rows at one passage of the machine; and that, while the two-wheeled type is now popular, a four-wheeled tractor will be found even more desirable.

Gage and Clearance

The gage of the tractor would naturally be the average of the minimum and the maximum distances between the rows, since the wheels are not to be made adjustable laterally. Corn and cotton are grown normally in rows 3 to 4 ft. apart; therefore the average distance between rows is 42 in. The implement manufacturers have adopted a gage of 44 in. for implements to cultivate corn and cotton crops, which gives ample clearance laterally.

For ground clearance we can again turn to the implement manufacturers and benefit by their experience. They have determined that a center clearance of 32 in. is necessary for implements used in cultivating and laying by these crops at a time experience has indicated as proper for maximum yields. In lieu of other data we can adopt this as a minimum clearance for tractors for this purpose.

One or Two Men Per Tractor While Cultivating

Tractors have no eyes; they must be guided constantly. We propose to increase the speed very materially. We expect a single operator to do satisfactorily work that in the earliest stages of the crop was frequently unsatisfactorily done at slow speed and with the assistance of the eyes of the work animals. I am sure that it would prove disastrous when the crop is young and tender. After the crop grows hardier it may perhaps be possible to devise some sort of fenders to assist the operator, but I question the wisdom of using but one man per machine for this work. The constant jerking up of his head to see how to steer and down again to look at the implements to be assured that they are doing their work properly and not injuring the crop, would soon tire the operator so that he would have to quit or do slovenly work; adding expense to the cost of cultivating the crop which to me appears greater than that of another man to give undivided attention to the cultivating implements.

Harvesting the Crop

Harvesting is one of the largest items entering into the cost of producing crops. Every acre cultivated must be harvested, and the acreage devoted to hay is frequently harvested several times per year. The cotton and tobacco crops, a part of the corn crop and perhaps some of the other crops are still harvested by hand. But by far the majority of the harvesting is done with some form of harvesting machinery, such as binders.

Practically all forms of harvesting machinery are designed with a cutter-bar, or some other harvesting device, extending to one side of the machine. The work animals are hitched ahead of the machine. Thus the power is ahead and

the resistance to one side. This causes a slueing tendency, and frequently the machines do slue, especially with heavy crops. When tractors are used to replace the work animals on these machines the slueing tendency is undoubtedly aggravated.

With the cutter-bar to one side and to the rear of the operator it is impossible for him to keep his eyes constantly on it, whether the motive power is work animals or a tractor. As a result the cutter-bar is frequently run into an obstruction. When this occurs with work animals they feel the tug and stop, and as a rule no damage is done. Tractors, however, have no feelings, and, the resistance of the cutter-bar being insufficient to overcome the power of the tractor, it is broken. This puts the implement out of commission until it can be repaired or replaced, a serious interruption when harvesting.

The pushing of implements is not impracticable with a tractor. By properly attaching them to the tractor the weight of the latter can be used to hold them steady and against the work. Naturally, desiring to push an implement, the first impulse is to fasten it to the front of the tractor. This has been done by several designers of harvesting implements which were brought out in the past year or two. From what I can learn these implements or attachments did very efficient work. To fasten them to the front of the tractor apparently a rather elaborate system of braces and connections was found necessary. The operator of the tractor, seated behind the steering-wheel to the extreme rear end of the tractor, was unable to see what the harvesting implement was doing or where it was going. Therefore an additional man was placed, in one case, on the radiator of the tractor, to look after the harvesting implement and apparently to direct the tractor operator as to the course he was to steer.

If it is conceded that it is best to apply the power to the harvesting implement directly behind it and to push it rather than pull it, and also that it is not desirable to attach the implement in front of the tractor, we have but one other solution, to attach the harvesting implements to the rear of the tractor and run the tractor backward, or in reverse, thus pushing the implements. This arrangement has several decided advantages. The tractor is designed and built so that attachments can be fastened at its rear end.

To push implements efficiently and with ease by running the tractor in reverse, and to pull them by running the tractor forward, the steering-wheel will have to be arranged so that the operator can sit in front of it facing backward, relative to the tractor, when pushing implements, as well as sit behind the steering-wheel facing forward, relative to the tractor, when pulling implements. This arrangement will enable the operator to face in the direction the tractor is moving and steer it in perfect comfort. By arranging the steering-wheel in this manner and leaving it at the rear of the tractor the operator will have the implements directly before his eyes constantly, while giving his attention to steering the machine, because they will be in the line of travel of the tractor. This puts no extra strain on the operator and therefore the additional man needed when harvesting implements are fastened to the front of the tractor can be dispensed with. The saving thus effected each season will probably pay several times over any additional cost in building the tractor so that it can push implements when going in reverse and pull them when going forward.

Universal Central Control and Speeds

Granting that the tractor is to run in reverse when harvesting and forward when plowing or cultivating, and that it will have more than one speed in reverse and probably as many in one direction as in the other, it is decidedly desirable to equip it with a universal central control, by which I mean an accessory, that will enable the operator to run the tractor, as readily when pushing implements as when pulling them.

The tractor should always be equipped with an extremely slow speed of great power, much slower than any normal working speed. This speed is to be used on heavy grades or in bad ground and might be fixed at approximately 1 m.p.h.

The tractor should be provided with a "plowing speed," a speed at which the drawbar-pull is sufficient to overcome the resistance readily, under the severest normal conditions, of the number of plows it is designed for. This speed has been fixed, for the present at least, by the Society of Automotive Engineers, at 2 1/3 m.p.h. for tractors having a drawbar horsepower of 15 or less. This would cover the machines here under discussion. How long this rate, in fact any rate, will remain standard will depend on the degree of success met with in the many tests now being made by the advocates of higher-speed plowing.

The power required to overcome the resistance of the ordinary cultivating implements is less than that required for plows when breaking land in the same soil. Many advocates of two or more machines per farmer point to this fact as being in favor of their position, because an engine operates more efficiently and economically when working under its normal load. Since the drawbar-pull for cultivating requirements is less than for plowing, why not increase the speed when cultivating until it multiplied by the cultivating drawbar-pull equals the plowing speed multiplied by the plowing drawbar-pull, when the power requirements would be equal? This would not only permit the engine to be operated under the most efficient and economical conditions but enable the tractor to cover much more of an acreage in a given time, thus reducing the cost of the work. It may be argued that a speed for cultivating to use the full power of the engine would be too great to permit the operator to cultivate properly. That is true when but one man is used for this work. However, I have already shown that it is highly improbable that one man can cultivate properly with a tractor at the ordinary speeds. With two men, however, one giving his entire attention to steering the tractor while the other gives his entire attention to the cultivating implements and the proper cultivation of the crops, this objection would probably be entirely overcome. In fact it is quite possible that better work would be done under those conditions, that is, at higher speeds with two men, because the work would be coming fast enough to demand their entire attention all of the time, thus giving them no opportunity to get slovenly about their work. It may be assumed that the position here taken is inconsistent with the one advocating two men while cultivating. I do not think so, for, in advocating two men while cultivating, the matter objected to was the incessant changing of the work from that of steersman to that of cultivator and back.

So far as I know no data have been published giving the drawbar-pull for plows when breaking land and for cultivating implements when cultivating that same land. I suggest an increase of about 50 per cent over the plowing speed, or say, for the present fixing the cultivating speed at about 3¼ m.p.h.

Summing up, we may fix, from the present knowledge of tractor speeds, desirable speeds for a tractor for the general farmer, about as follows:

First, or "trouble speed," 1 m.p.h.
Second, or "plowing speed," 2.33 m.p.h.
Third, or "cultivating speed," 3.75 m.p.h.
Fourth, or "road speed," 5 m.p.h.

The position may be taken that so many speeds in reverse are not necessary. It will be shown under "Power for Attachments" that there will be a decided advantage in having a number of speeds for harvesting implements, and, in accordance with the position here taken, this work is to be done with the tractor traveling in reverse.

Belt Work

Tractors should, of course, be equipped for belt work. Most, if not all, of them are equipped with proper gearing, a clutch and a belt pulley. The Society of Automotive Engineers has adopted certain speeds as standard so that not only tractor designers know what speed to give the belt pulley of the tractor, but designers of farm equipment requiring power can be assured of having their equipment run at the proper speed for best results by giving that equipment a pulley of the right diameter. There is one point, however, that it

seems might receive some attention. The pulley, to be effective and readily lined up with the pulley of the equipment to be driven, should extend beyond the frame of the tractor. This construction, while of advantage in lining up the belt pulleys, is not desirable at other times. The pulley, extending beyond the frame, is liable to catch on obstructions or gate-posts, which may result seriously, even to bending the pulley shaft. The season for using the pulley is a limited one and it usually comes all at one time. The rest of the time the pulley is an incumbrance. Why not make the pulley readily detachable and as readily reattachable in only the correct way?

Flexibility

By "flexibility" is meant a design of frame that will enable two of the wheels to oscillate about a common horizontal longitudinal axis in such a way that all four wheels can remain on the ground when moving over rough terrain or drainage ditches, without in any way warping the frame of the tractor. This is necessary to assure ease of operation and long life, and to make the tractor as light in weight as possible, for, if sufficient flexibility is not provided the frame of the tractor must be made sufficiently strong to overcome the warping tendency when the tractor moves over rough ground or farm ditches, and therefore heavier, or the engine, transmission, etc., will be thrown out of alignment, which will reduce the life of the tractor.

Wheels

Tractors should be equipped with as large wheels as is practicable. Small wheels make it difficult to pass over rough ground and drainage ditches without danger of stalling the tractor; tractors are frequently stalled because of small wheels. Furthermore, considerably more power is consumed in propelling a tractor with small than with large wheels.

Springs

Spring mountings should be used to as great an extent as possible without tending to make the tractor more complicated and therefore increasing the cost of maintenance. Simplicity of design with springs tends to reduce the wear-and-tear on a tractor and increases the comfort of the operator very considerably.

Weight

The tractor should be built as light in weight as is consistent with proper strength and traction. Only sufficient weight is necessary to cause the lugs to penetrate the soil to their full depth while the tractor is at work, thus enabling it to develop its full drawbar power. Sufficient weight, in the case of tractors having their drive-wheels in the rear, should be placed over the front wheels to keep them from leaving the ground or rearing up when the tractor is exerting its maximum drawbar power or when going up any incline that may reasonably be expected in the ordinary performance of its duties. While much has been done in reducing the weight of the better designed tractors it seems reasonable to expect that still more can be accomplished by the use of steel and other alloys in the frame and in other places without interfering with the traction or the power of the machine, and also not reducing the weight on the front wheels unduly.

Special Attachments

Farmers' Bulletins Nos. 719 and 963 both contain a statement from which the following extract is taken:

> It is obviously impossible to obtain maximum results with a tractor when it is used with implements designed primarily for use with horses, and the objection of many tractor owners that the tractor cannot be used with profit for certain types of field work will probably cease to hold good with the development of special machinery for use with the tractor

This merely voices the sentiment of practically every one who is giving much thought to the ultimate design of the tractor. The tractor must be a complete machine and ultimately will be designed as a complete machine, attachments and all.

Power-Lift

There seems to be no reason why a power-lift cannot be included in the design of the complete machine, so that the attachments can be raised and lowered by the power of the engine on the tractor. This accessory could be very simple and inexpensive. It would increase the cost of the complete machine very little. The farmer would gladly pay for the increased convenience.

Power for Attachments

There is no reason why attachments requiring power for their proper manipulation cannot derive it direct from the engine on the tractor instead of having the power passed from the engine, through the tractor drive-wheels, then through the bull wheel of the attachment or implement, as is now done with animal-drawn implements, such as mowers and binders. The engine supplies the power in any event. Why not by the most direct and least power-consuming way? One tractor building company has recently recognized the desirability of this feature by bringing out a model that has a connection to supply power to one of its implements direct from the engine. This accessory could be made simply and inexpensively. It would not be necessary to equip it with a variable-speed transmission. Extra sets of gears or sprockets could be provided, should more than one speed be found necessary.

In the case of harvesting implements, such as mowers and binders, the supplying of power from the engine direct to the cutter-bar would be of distinct advantage. The cutter-bar could be operated at such a constant speed as experience has indicated produces the best results. Then the tractor could be run at a speed that would, as nearly as possible, feed the crop to the cutter-bar at its full capacity. The running of the cutter-bar at a constant speed and the tractor at a variable speed while harvesting is made possible through equipping the tractor with more than one speed in reverse.

Fool-Proofness

Tractors are not infrequently placed in the hands of unskilled and even ignorant labor. Therefore it is positively essential to make them as fool-proof as possible. All gearing should be housed to prevent accident, if this has not already been done to permit efficient lubrication and to reduce the wear and the power required to move the tractor. The manipulation of the tractor should be made as simple and as easy as possible. Attention to all of these points will increase the efficiency of the operator and enable him to accomplish more work in a given time, reducing the cost.

Summary

Therefore the query, "What form will the tractor ultimately take?" may be very largely answered by stating that it will be the form that will embody the features that will enable the general farmer to do in a more economical and efficient manner all of the work on his farm that he is now doing with work animals and portable engines.—From a paper by W. C. Zelle presented to the American Society of Agricultural Engineers.

Artificial versus Natural Means of Drying Paint and Varnish

By R. E. Lippert

Cleveland Section Paper *Illustrated with* Photographs and Drawings

THE author describes a process for drying coats of paint and varnish more rapidly than is possible with natural means, by adding heat and moisture simultaneously to the air surrounding the siccative coatings, through the employment of mechanical devices. The use of a fan and conditioning equipment to produce air circulation allows the process to be adapted readily to modern factory-schedules.

Atmospheric conditions suitable for drying are discussed at some length as being a composite of sensible temperatures and relative degrees of humidity, and several humidifying devices are described and illustrated. Color control of paint by this means of drying is mentioned, examples being given, and numerous photographs showing installations of artificial drying equipment in use at various automobile plants are presented.

THE paint-shop seems to be the one department in the automobile business that did not receive due consideration when the industry was established on a quantity-production basis, and as a general rule this department does not make as favorable a showing as the other departments of the plant. The obvious solution is to adopt better and more efficient methods so as to multiply the output per man and per unit of equipment. The process I will describe provides a means for drying coats of paint and varnish more rapidly, thereby putting the paint-shop on a quantity-production schedule without sacrificing the quality of the work produced. This process eliminates the uncertain element of time by enabling the manufacturer to establish a fixed production-schedule that will function uniformly in spite of constantly varying weather conditions. In its simplest form the process consists of simultaneously adding heat and moisture to the air surrounding the siccative coatings of paint or varnish. The use of a fan and conditioning equipment to produce air circulation allows the process to be adapted more readily to modern factory schedules, but the underlying principle is the same today as it was when the process was discovered by Dr. William H. Grosvenor 15 years ago.

Paint and varnish will air-dry successfully, because air always contains some moisture and some degree of heat, but successful air-drying depends entirely upon storage facilities, weather conditions and other factors. The drying time varies with atmospheric conditions and, since it does vary, there must be at least one definite condition under which a certain grade of paint or varnish will dry most rapidly and successfully. When such a condition is once established, it should be maintained uniformly throughout the entire drying period, and it should be possible to duplicate the condition and eliminate the element of chance whenever and wherever desired. Nature herself may, somewhere and at some particular time, furnish weather conditions somewhat approximating the degree of heat and moisture required to dry paint and varnish properly, but the most favorable and most unusual of such natural weather conditions are variable, of short duration and of unforeseen termination. Moreover, so many different grades of paint and varnish exist, containing such varying proportions of oxidizable oils, that it is manifestly impossible to establish one standard ideal atmospheric condition for drying each of them, and it is absurd to expect nature to comply with so many different sets of specifications. Thus the necessity arises for supplementing natural atmospheric conditions with some artificial means of (*a*) establishing an ideal drying atmosphere at will, (*b*) maintaining such an atmosphere uniformly for the drying period, and (*c*) being able to duplicate or vary this condition as desired.

Unfortunately, atmospheric conditions are measured not only in degrees of temperature, but also in percentages of relative humidity. The mere fact of maintaining a uniform temperature does not presuppose a uniform relative humidity, unless means are provided for adding moisture and controlling such additions by proper me-

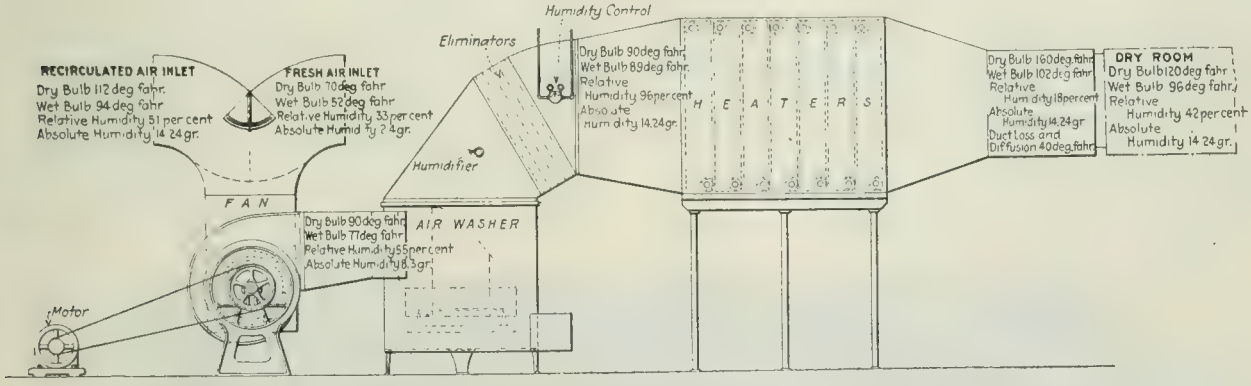


Fig. 1—Diagram Showing the Operation of an Indirect Heating System Equipment with a Combination Air-Washer and Humidifier

[1]A.S.A.E.—Sales engineer, Drying System, Inc., Chicago.

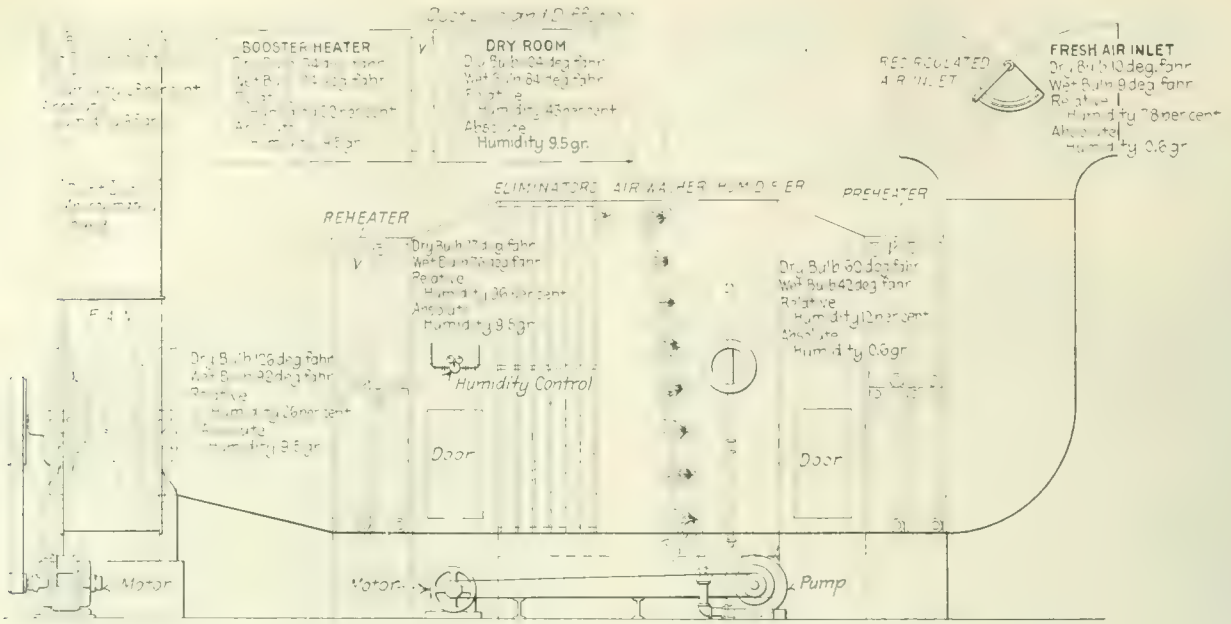


FIG. 2—A TYPICAL VARNISH DRYING INSTALLATION WITH A SPRAY-WASHER

chanical devices. The moisture content of the air is fully as important a factor in the drying of siccative coatings as the temperature of the air itself. When the idea of artificially drying paint and varnish was first conceived, it was the general belief that moisture would retard rather than hasten the drying process. Several years of earnest endeavor was required to prove the contrary. In fact, the true value of humidity was not appreciated even after several installations of humidity-equipped drying-systems were made and tried. Its only then-apparent value to the trade was to prevent surface or so-called case-hardening but, as a matter of fact, the main reason for adding moisture is that the moisture acts as a catalytic agent and cooperates with the increased heat in performing the chemical reaction of oxidization. This is the important function in the drying of any siccative coating, and it is entirely foreign to the purely physical evaporation of volatile solvents.

Having established the fact that certain definite atmospheric conditions are not only desirable but necessary, and being convinced that nature can provide such conditions only on rare occasions, it becomes necessary to furnish the proper mechanical means for creating artificially suitable drying weather to produce a standard finish of good appearance and greater durability. If we concede the value of humidity, the simple installation of steam coils will not suffice, even if they are thermostatically controlled. Let us assume, for example, that a certain grade of varnish will dry perfectly in a dryroom having a temperature of 120 deg. fahr. and that a relative humidity of 42 per cent means that there must be 14.3 gr. of moisture per cu. ft. of air. To duplicate such a condition in a

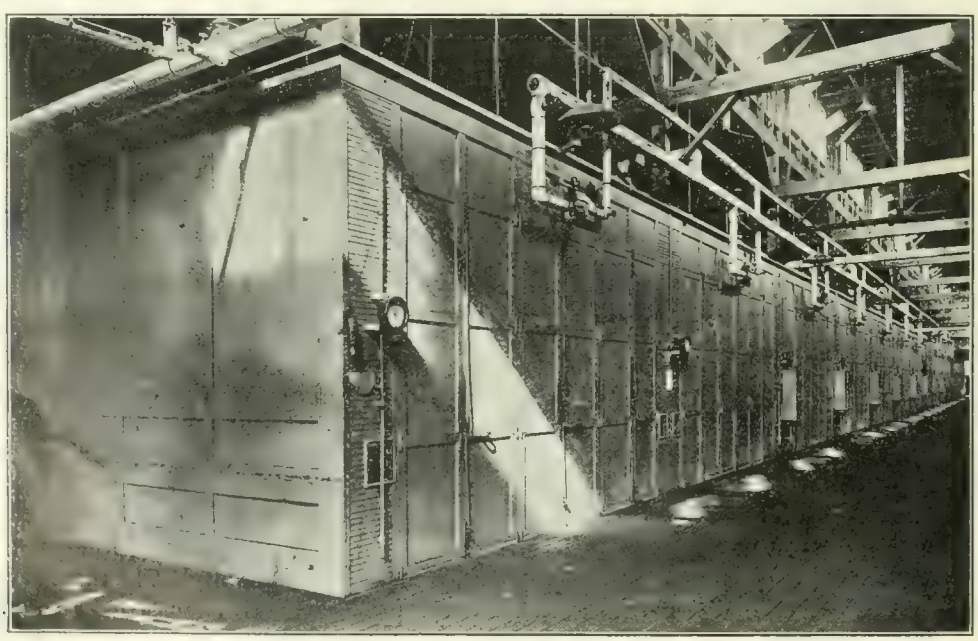


FIG. 3—A SERIES OF BODY DRYROOMS INSTALLED ABOUT EIGHT YEARS AGO THAT POSSESSES SUFFICIENT CAPACITY TO HANDLE 50 BODIES PER DAY ON A 12-COAT SCHEDULE

FIG. 4—A DRYROOM IN WHICH THE BODIES ARE RUN IN ON SMALL WHEELED TRUCKS

dryroom containing only steam-coils would necessitate an outside temperature of from 90 to 100 deg. fahr. with relative humidities ranging from 73 to 100 per cent. It is a matter of record, however, that in the vicinity of Cleveland the average moisture-content of the air ranges from about 1 gr. per cu. ft. in January to about 6 gr. per cu. ft. in July. But air at natural temperatures containing 1 gr. per cu. ft. when heated to 120 deg. fahr. will have only a relative humidity of about 3 per cent and even the maximum of 6 gr. per cu. ft. results in only a relative humidity of 18 per cent at that temperature, whereas 14.3 gr. is required to produce the desired results. Hence, some suitable means must be provided to make up the deficiency in the moisture content of the drying air if we propose to establish a uniform condition, and it merely becomes necessary to select the most suitable means.

HUMIDIFYING DEVICES

We have tried and discarded a great number of humidifying devices such as water-pans, water-screens and steam-jets. Our best results have been obtained by the use of an indirect heating system equipped with a combination air-washer and humidifier. In this way we have not only obtained accurately controlled conditions of temperature and humidity, but it has been possible to eliminate dust, dirt, insects and other foreign matter from the drying air. Fig. 1 gives a general idea of how and why this type of drying equipment operates and shows a typical section of such an equipment consisting of a motor-driven fan, an air-washer and humidifier, a series of steam-coils or radiators, temperature and humidity controlling devices and a duct system for air supply, circulation and ventilation. The ducts, which are not shown, are arranged in a suitable manner so that the conditioned air is uniformly distributed. From the standpoint of economy, it is customary to recirculate the air partially and hence two connections to the fan inlet are provided. To afford a concrete example of the action that takes place as the air passes through the machine, let us assume that it is desired to operate a dryroom at a temperature of 120 deg. fahr. and a relative humidity of 42 per cent on a day when the shop temperature is 70 deg. fahr. and the relative humidity 33 per cent. Since the duct loss and diffusion within the dryroom will necessarily cause some heat loss, which is assumed to be 40 deg. fahr., it will be necessary to raise the temperature of the air from 70 deg. to a final temperature sufficiently in excess of 120 deg. to compensate for this loss and to increase the moisture content from 2.4 gr. per cu. ft. or 33 per cent at 70 deg. fahr. to 14.3 gr. per cu. ft. or 42 per cent. at 120 deg. fahr.

It is desirable to recirculate part of the air; so, in this case it is assumed that 50 per cent is fresh air from the shop and 50 per cent is air recirculated from the dryroom. From past experience we have found that the recirculated air will return at a temperature of about 112 deg. fahr., with a 14.3 gr. per cu. ft. moisture-content, and a mixture of the two when delivered to the air-washer will have a temperature of approximately 90 deg. fahr. and an actual moisture-content of approximately 8.3 gr. per cu. ft. This mixture then enters the air-washer. The air and water come into intimate contact with each other and any drop in temperature sustained

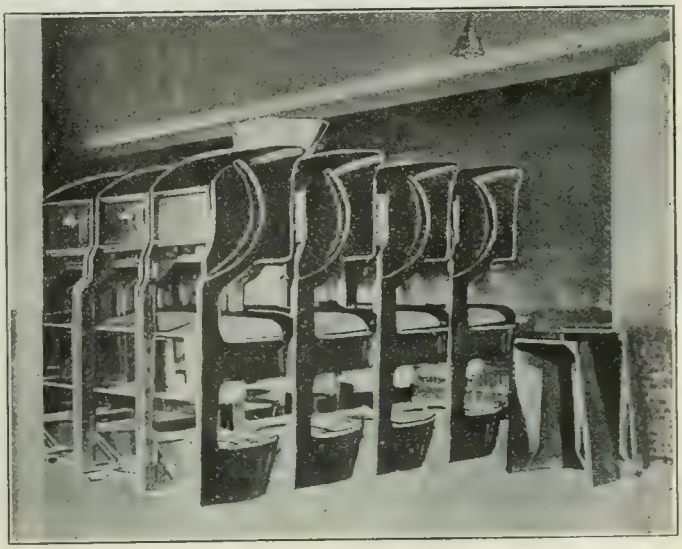


FIG. 5—INTERIOR VIEW OF A DRYROOM IN WHICH THE BODIES ARE UP-ENDED

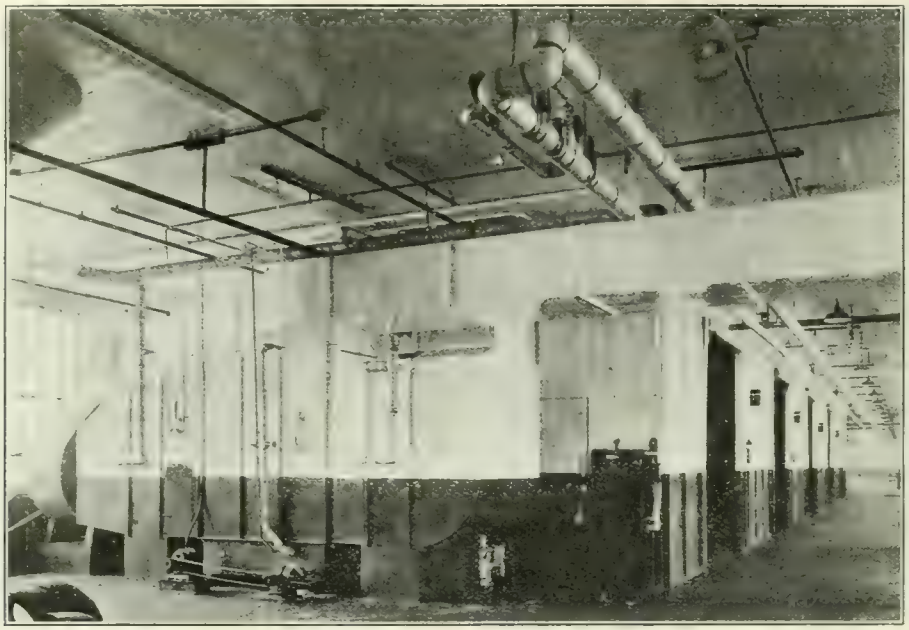


FIG. 6—A SERIES OF COLOR VARNISH DRYROOMS OPERATED BY AN EQUIPMENT HAVING A DAILY CAPACITY OF 150 BODIES

here is made up when the air passes through the steam humidifier, which also completes the saturation. The air after passing the washer has therefore reached a temperature of 90 deg. fahr. and carries the requisite 14.3 gr. of moisture per cu. ft. It shows a relative humidity at this stage of 98 per cent, or practically complete saturation, and the only operation that remains is to raise the temperature to 160 deg. fahr., which is the desired dryroom temperature of 120 deg. plus the assumed duct and diffusion loss of 40 deg. This can be done without any loss of absolute humidity. The heaters are either cast-iron radiators or pipe coils fed by one common manifold. The steam supply system is equipped with a diaphragm valve that is operated automatically by an expansion thermostat located in the dryroom. When the air has passed the heaters it will be virtually at 160 deg.

FIG. 7—DARK ROOMS FOR FINISHING VARNISH

In This Plant the Finishing Coat Is Applied during the Day and Dries at Night so That the Bodies Will Be Ready for Final Assembly in the Morning

fahr., with only 18 per cent of relative humidity at this point, but the absolute humidity still remains at 14.3 gr. per cu. ft. and the final condition obtained in the dryroom will be correct both as to temperature and humidity.

We have found the most successful method of controlling humidity to be the dew-point control. The principle of its operation is that the amount of moisture that air can carry at saturation is dependent on its temperature. For instance, having determined that a relative humidity of 42 per cent at a temperature of 120 deg. fahr. is desired, we know that an absolute humidity of 14.3 gr. of moisture per cu. ft. must be provided. Our humidity tables show that a moisture content of 14.3 gr. per cu. ft. represents saturation at a temperature of 90 deg. fahr.; the dew-point for this condition, therefore, is 90 deg. and by simply setting the humidity control for that temperature the desired result is obtained. Fig. 2 shows a typical varnish-drying installation with a spray washer which operates on the same general principle as the static type. We use this kind only when the capacity of a single unit exceeds 15,000 cu. ft. per min., because the first cost of a static washer is much lower than that of the small spray machines that require a motor-driven pump to force the water through the nozzles; otherwise the features are the same as for the static washer.

COLOR CONTROL

We have found that it is possible to establish an absolute color standard by this means of drying, even with the most delicate colors. The proper use of humidified air will eliminate the troubles resulting from off-color painting jobs, especially when using light blue, yellow, white or gray. Tests recently conducted with five different shades of blue demonstrated conclusively that the colors dried under proper humidity conditions could not be distinguished from those that were air-dried. Further, it was found that each one of the blue samples required a different relative humidity to produce the same likeness as was shown by its air-dried counterpart. For example, body No. 1 was dried with a relative humidity of 35 per cent at 130 deg. fahr. and showed a greenish overcast; but body No. 2 coated with the same varnish and dried with a relative humidity of 45 per cent could not be dis-

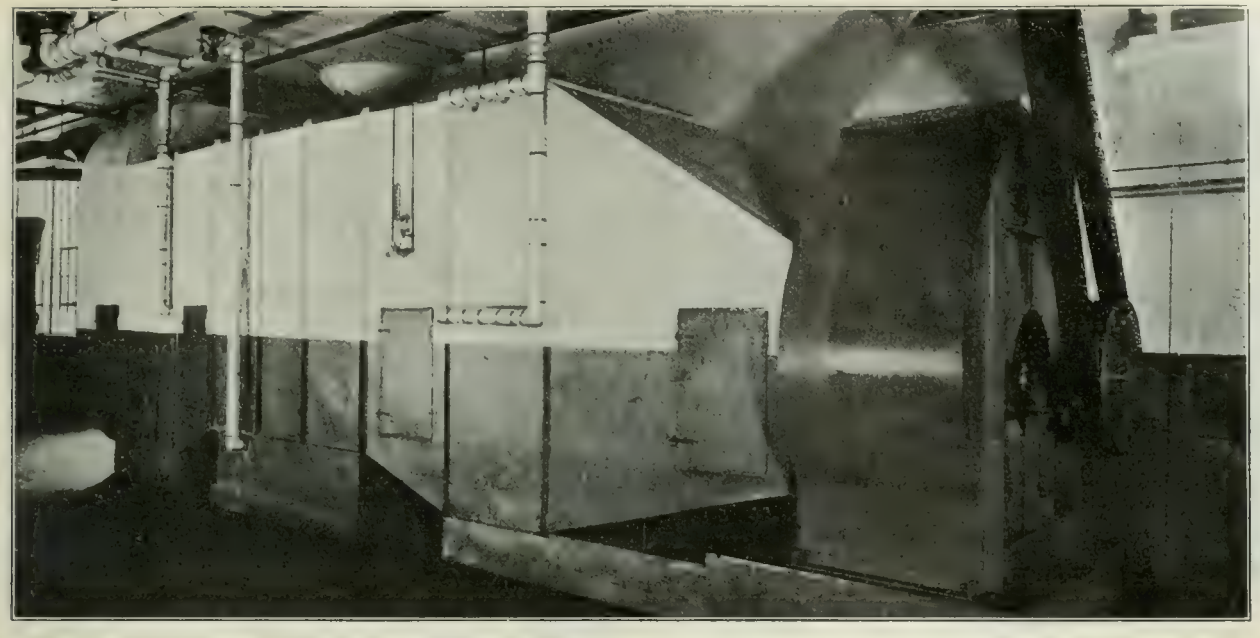


FIG. 8—CLOSE-UP VIEW OF THE EQUIPMENT OPERATING THE DRYROOMS SHOWN IN FIG. 7

tinguished from the air-dried sample. Bodies Nos. 3 and 4 coated with a different shade of blue and dried with a relative humidity of 35 and 45 per cent respectively were both failures; but were produced perfectly true to shade with a relative humidity of 55 per cent. A temperature of 130 deg. fahr. was used for all tests. We have worked out a table for practically all the known colors used in the industry. The only way to dry such colors successfully is to establish a schedule of temperatures and humidities that can be duplicated whenever required.

INSTALLATIONS OF ARTIFICIAL DRYING EQUIPMENT

Fig. 3 shows 10 body dryrooms that were installed in a Detroit motor-car plant about eight years ago. Seven of the rooms are 20 x 30 ft. and three of them are 20 x 45 ft. The total installation is sufficient to handle 50 bodies per day on a 12-coat schedule. The equipment recently installed at the assembly plant of a popular-priced car is arranged so that the bodies are up-ended on a conveyor that runs through the dryroom which measures 24 x 164 ft. With this equipment they are handling 300 touring-car bodies per day on a two-coat low-temperature enamel schedule. Fig. 4 shows an installation at a plant in Toledo where the bodies are not up-ended. Fig. 5 is an interior view of a dryroom where the bodies are up-ended. Fig. 6 shows a series of color varnish dryrooms operated by one equipment designed for 150 bodies per day; another equipment at the same plant is used for the block-off and striping work. Fig. 7 shows the dark rooms for finishing varnish, the finishing coat being applied during the day and dried overnight so that the bodies will be ready for final assembly in the morning. Fig. 8 shows a close-up view of the equipment that operates the dark room. This delivers 30,000 cu. ft. of air per min. With one machine of this kind it is possible to operate a series of rooms. By equipping each room with a set of booster heaters individual control is obtained and each room can be operated as an independent unit.

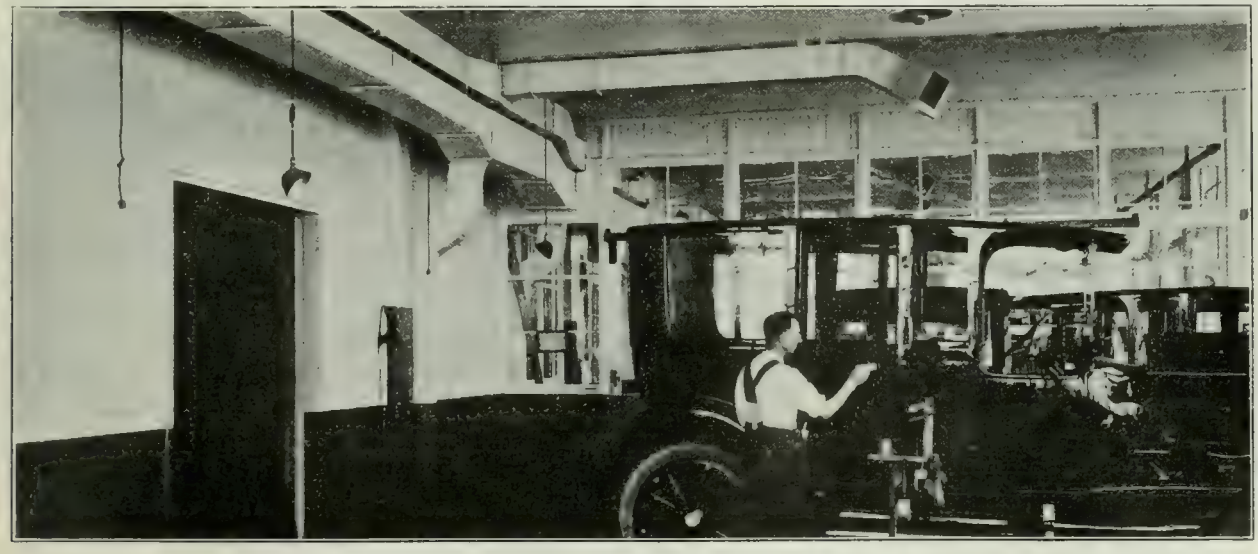


FIG. 9—A COMBINATION FINISHING AND DRYING ROOM

The Finishing Coat of Varnish Is Applied during the Daytime under the Most Favorable Temperature and Humidity Conditions and in the Evening the Automatic Controls on the Equipment Are Changed so That the Bodies Can Be Dried Overnight

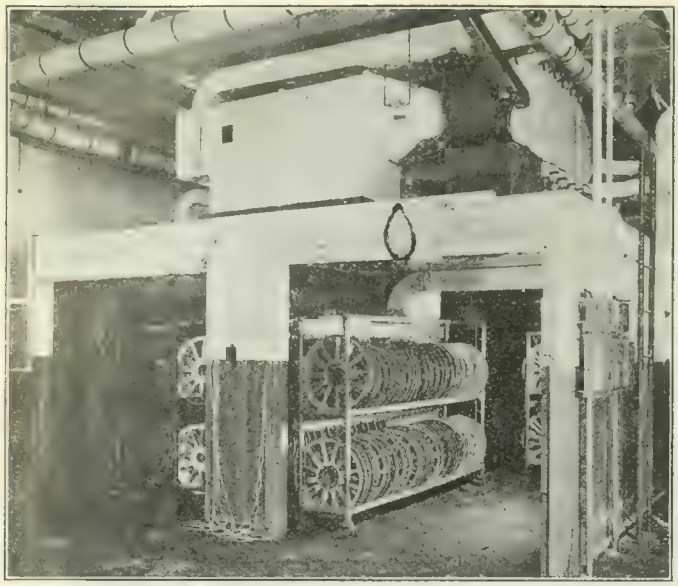


FIG. 10—A BATTERY OF WHEEL DRYING ROOMS

Fig. 9 shows the combination finishing and drying room at a plant in Buffalo. Throughout working hours this machine maintains the temperature and humidity best suited for applying the finishing varnish. In the evening the automatic controls are changed and the same equipment dries the bodies overnight at a temperature of 104 deg. fahr. and a relative humidity of 48 per cent. The bodies are mounted on their chassis, which appears to be a very satisfactory method for high priced cars produced in small quantities, but when running on a large-production schedule it would not pay because the space occupied by a completely mounted body is too great. One of the most important features of this type of installation is that it eliminates the dust and dirt and still provides fresh ventilated air in which the men can work. In summer an 8 or 10-deg. temperature-variation between the inside and the outside air is highly appreciated by the men who do the work. At a test recently conducted in a finishing room similarly equipped we were able to maintain an inside temperature of 86 deg. while the temperature outside registered 94 deg.

Fig. 10 shows a battery of wheel dryers recently installed at a Detroit factory. Little, if any, changes from earlier installations have been made in the method of handling the wheels. Fig. 11 is an interior view of the dryroom at a plant where the assembly line is combined with chassis-painting operations. A room of this size with a 45-min. drying period will handle about 125 jobs per day. Fig. 12 shows another chassis dryroom and the return-line for empty trucks. Fig. 13 illustrates a motor-truck installation that shows the adaptability of the system to other than passenger-car work and also indicates detail of the cable-type conveyor with which this dryroom is equipped.

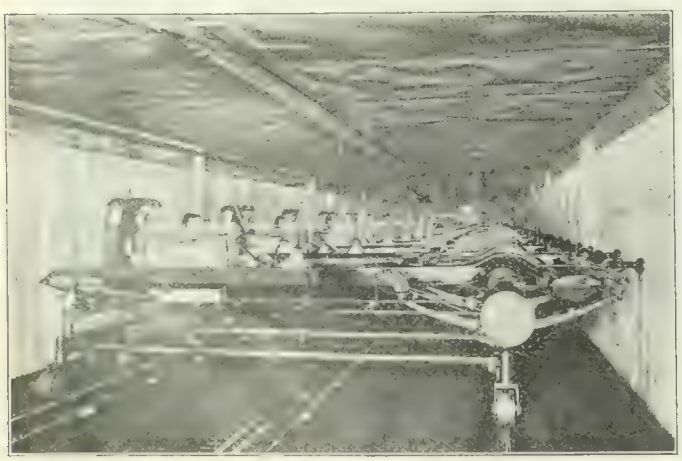


FIG. 11—INTERIOR VIEW OF A DRYROOM HAVING A DAILY CAPACITY OF APPROXIMATELY 125 BODIES BASED ON A 45 MIN. DRYING PERIOD IN THIS PLANT THE ASSEMBLY LINE IS COMBINED WITH THE CHASSIS PAINTING OPERATIONS

Some of the illustrations were taken seven or eight years ago and are offered as evidence that aside from some material improvement in the type of drying equipment used there has been no radical change in paint-shop production methods. While a reliable drying equipment will solve the underlying difficulties it seems that some actual changes in the production methods are necessary to put the paint-shop on the same efficient operating basis as the remainder of the plant. It is safe to assume that in no other department of the plant can such a large saving of money be effected by the installation of modern equipment. A preliminary investigation of this matter is now under way and I believe that a system has been devised whereby an automobile body can be completely finished and trimmed, using a standard 12-coat schedule, in four and one-half working days, at a saving of between $6 and $7 per body. To a plant producing 200 cars per day this represents an annual saving of $400,000 which, measured in banking-house terms, represents 6 per cent interest on over $6,000,000.

THE DISCUSSION

JOHN MCGEORGE:—From what has been said I gather that the term "drying action" amounts to nothing.

R. E. LIPPERT:—It is a drying action only in name. It is really a double action; first, the purely physical reaction exemplified by the evaporation of the volatile solvents; second, the chemical reaction effected by the oxidation of the oils. When linseed oil is oxidized, linoxid is produced.

MR. MCGEORGE:—Would you call that a baking?

MR. LIPPERT:—It is not a baking. If water is evaporated from a pan, its chemical composition is not changed; it is only converted from a liquid to a vapor. When benzine or any volatile liquid is evaporated, the same thing is true. But when an oil is changed by oxidation the molecules are broken up and it is changed chemically as well as physically. Even the baking of enamel is both a physical and a chemical process because practically all enamels are made of products containing some linseed oil; while some enamels have little or no oil in them, the ordinary enamel is different from paint or varnish only in the respect that it must be heated to higher temperatures, and therefore we bake it at from 350 to 450 deg., the term "bake" probably being applied because of the excessive temperatures used. In the baking period there is a burn-off, so called because the volatile fumes are visible, followed by an oxidation corresponding to the oxidation that takes place in paint or varnish. There are certain low-temperature enamels having a high percentage of oil that will react exactly like paint or varnish and dry more satisfactorily in humidified air, but I am unable to say whether the same condition holds good for enamels or Japans which are burned off and baked at high temperatures. I presume that the most important need for high-temperature enamel is the production of a surface of enough elasticity to stand up under the usage that hoods and fenders get.

J. A. WILLIAMS:—If the practical painters present

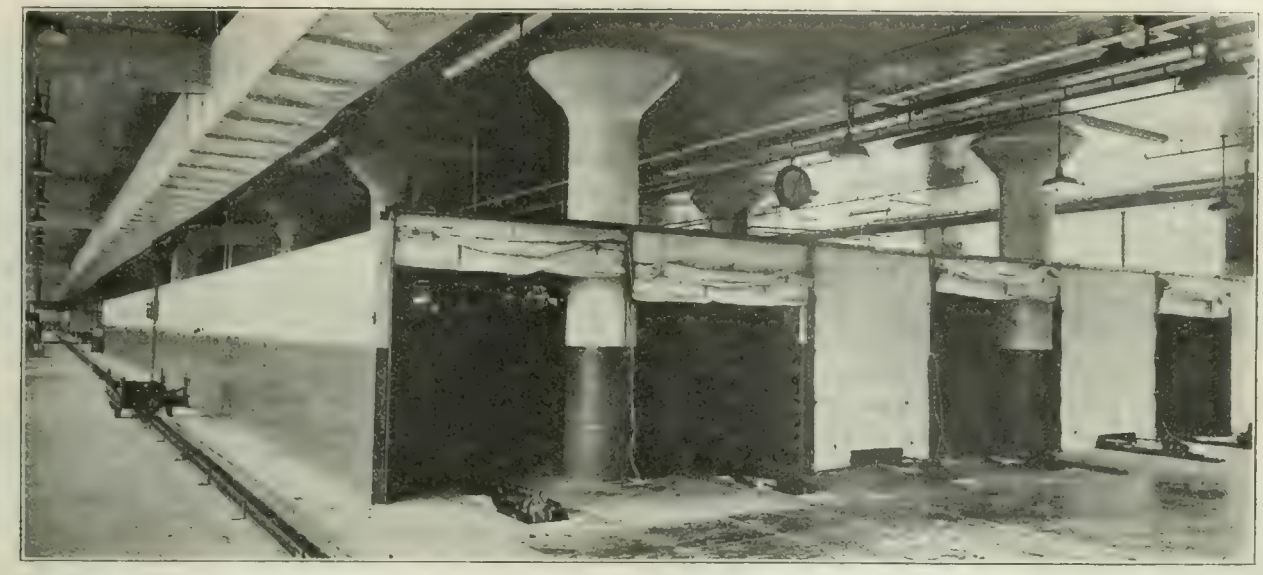


FIG. 12—ANOTHER CHASSIS DRYROOM EQUIPPED WITH A MECHANICAL CONVEYING SYSTEM
In This Plant the Trucks on Which the Chassis Are Carried Through the Dryroom Are Returned when Empty by the Conveyor at the Left of the Illustration

would express themselves, their testimony probably would be contrary to the impression created that it is impossible to produce a painted job correctly unless an artificial drying system is used.

MR. LIPPERT:—I said that it would be possible to dry and oxidize paint and varnish properly under ordinary air conditions if one had the space and time to do this, but modern production requires methods other than air drying. Although air-drying may be satisfactory with a small production and plenty of room, one cannot afford to depend on the weather when producing 200 jobs per day. Is it not true that on certain days a varnish may dry in ordinary air in 24 hr. and that the next day it may require 30 hr.?

MR. WILLIAMS:—I understand that the drying equipment described is good for handling quantity production as required at present, because it forces the drying of varnish regardless of the quality, but there are painters here who know that varnish can be dried successfully without the aid of artificial apparatus. On the seaboard the salt air will go through the artificial drying apparatus.

MR. LIPPERT:—That may be true. We do not dispute the fact that varnish can be air-dried; we are merely trying to establish a uniform condition for drying without forcing the varnish. We predetermine a condition under which a certain varnish will dry most successfully; then we create and control that condition. That is not forcing the varnish. With the proper temperature and humidity one can dry paint or varnish and guarantee a more durable and a better looking finish, whether the drying is done in salt air or not.

As to salt air, I am not sure that there is actually any salt in the air; when moisture is picked up by air in the

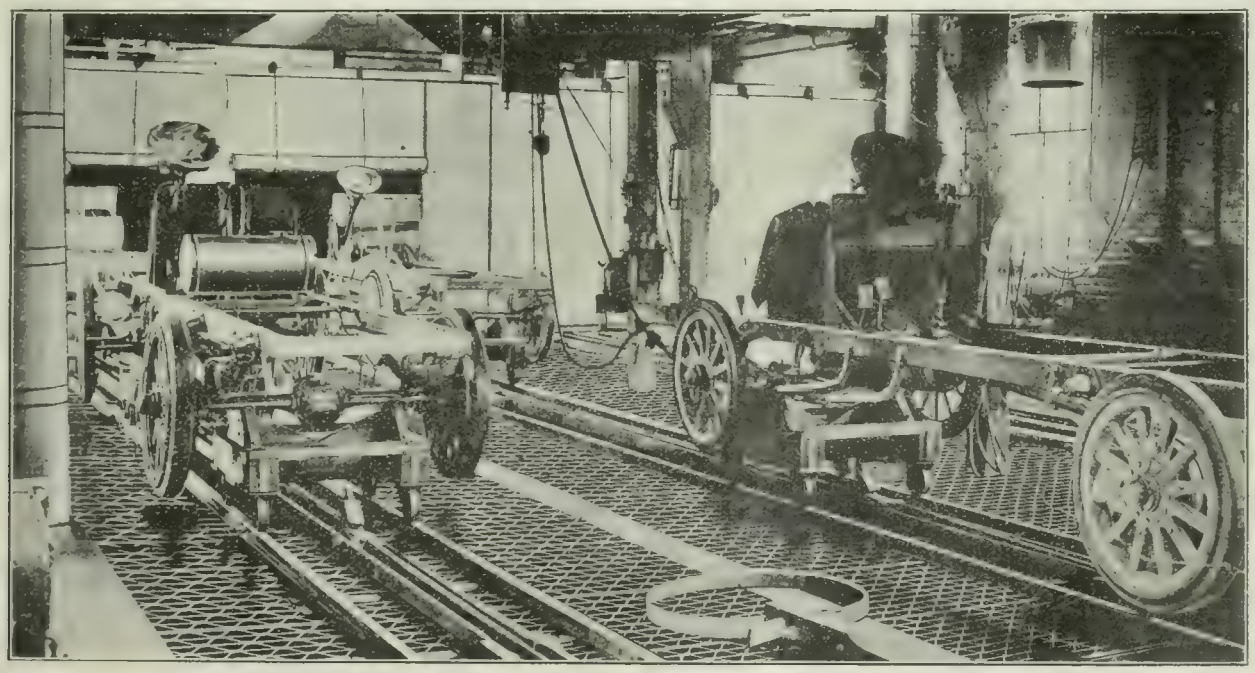


FIG. 13—DRYROOM IN A MOTOR-TRUCK PLANT EQUIPPED WITH A CABLE-TYPE CONVEYOR

form of water vapor it does not carry the salt with it. Moisture is absorbed by the air through an evaporation process and the moisture in the air is really distilled water. Any chemist will agree that the first requisite of distilled water is that it must not contain chlorine.

A MEMBER:—What is the property of paint that makes it suitable for ocean work? During the war many of the trucks that were sent abroad were bare of paint when they arrived.

MR. LIPPERT:—I do not know. Ocean air may have a corroding action.

A MEMBER:—Is that caused by the salt in the air?

MR. LIPPERT:—It may be due to entrained moisture in the air. Our experience in this respect is limited because 90 per cent of the production of automotive vehicles is in plants located on fresh water lakes. The number of cars that are turned out on the Atlantic and on the Pacific coasts is small and the producers are small firms, most of them buying their bodies from some body builder not located on the coast. However, one important body-building firm located near New York City is using an artificial drying system and would not be without it. The system works properly and no difference has been noticed in the finish. As a matter of fact, it ought to make very little difference whether a varnish is air or artificially dried; provided that it is completely dry, the resulting coat is the same in either case. However, we are not interested in the effect of ocean air on the varnish in the can or on the apparatus by which it is dried, but rather in its effect on the dry coating and, if ocean air affects an artificially dried coating, it will undoubtedly have the same effect on an air-dried one. Another consideration that favors artificial drying is that present-day varnishes are made primarily for this purpose and not for air-drying. Six years ago a varnish that could be air-dried in 96 hr. could be dried artificially in 12 hr. Today, there are ordinary 12-hr. varnishes that can be dried artificially in 3 hr. or less.

K. B. BRITTON:—One firm that is using artificial drying equipment has had a number of complaints that the varnish on cars used along the seacoast lost its luster.

MR. LIPPERT:—If such complaints are due to improper drying they should be brought to the attention of the builder of the apparatus. What kind of varnish is most suitable for seacoast work?

E. T. BIRDSALL:—The paint and varnish business is extremely complicated. It probably affords greater opportunity for substitutes than any other business, aside from the oil and grease business. In making paints and varnishes in the days when nothing but linseed oil, gum and turpentine were used, good paint and varnish were produced and a slow-drying varnish gave the best results. Then oxide of lead was used and it hastened the oxidation of the oils. At present there are all kinds of gums; some come from China. There are also all sorts of oils. The Standard Oil Company produces a fine line of driers. One can get any kind of gum or any oil desired except linseed oil, at any price. It is known that if one wants to make a cheap varnish, resin is put into it. Laundry soap is one-third resin. I know of one factory that fired its boilers every year with the staves of resin barrels. Regarding gums, everybody has been trying to use resin. If a varnish is made with resin it will crack; it will crack also if gum and wood oils are used. Chemists have been studying the paint business for the past 7 or 8 years and found that resin can be used. Resin does not make good varnish; nor do wood oils, yet one can make a varnish or a paint with them. It was found that a mixture of resin and wood oil and a peculiar form of lead made as good a varnish as when linseed oil was used; in salt air, for example, the cheap varnish actually stood up better. The drying of an enamel is a distillation and the drying of paint is an oxidation process, although Mr. Lippert calls it "burn-off." Enough binder is left at 400 deg. to make a coating that will stand up. There is just as much substitution in the enamel business as in the paint business. One cannot judge quality until a car has been used a year. I see no reason why the finish coating should not be as good from the accelerated as from a slow process. All paints and varnishes are porous, and there is no reason why the temperature and humidity used in artificial drying should not act to the full depth of the paint and varnish coatings on the bodies.

A MEMBER:—An experienced paint and varnish man claims that he has obtained the best results in the spring and fall for a period of years. How can that be accounted for?

MR. LIPPERT:—The most suitable month of the year for air-drying under normal temperature is April. There is a corresponding month in the fall, although it is not as good as April. There is steam heat in the paint-shop in April and that provides a better condition than at any other season of the year. The Weather Bureau's records show that the humidity is at its lowest percentage in January and at its highest in July, varying from 1 to 6 gr. of moisture per cu. ft. of air. That statement of weather conditions shows that it is possible to obtain for the accelerated drying a condition that will do anything that the air-drying method will do. We know that air-drying is possible if sufficient time is available. We only claim that drying can be done successfully and properly in less time, without deterioration of the product, by the artificial process.

MR. MCGEORGE:—If we do not know the process of so-called drying we cannot make improvements. What is the reaction? It may be called burning or drying or chemical action. It cannot be burning. It may be burning in the sense of oxidation, but oxidation is a distinct chemical change. Drying is simply an evaporation of the moisture and that is not the action we are discussing. What is the change that occurs?

MR. LIPPERT:—The term "drying" as applied to varnish is a misnomer. The process is an evaporation and an oxidation. In drying oils the oil molecules are attacked, some of them are carried away and the residue is converted into a solid substance. The molecules carried away are combined with the oxygen of the air to form carbon dioxide and water. The residue is an oxidized gum.

A MEMBER:—Is the residue that is left detrimental to the luster of the varnish?

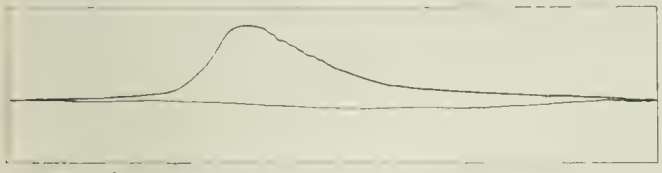
MR. LIPPERT:—The residue becomes the body of the varnish. The carbon dioxide that is formed when oxidation takes place is carried away by the air; that is why it is necessary to have sufficient air circulation to carry it away. We have found that if a room having steam-coils is closed up tight and the vapors are not carried away, a blanket is formed that gradually fills the room and surrounds the objects being dried, retarding the process. In other words, when the process of drying in a tightly closed dryroom is started, after all the oxygen in the air has been exhausted and it has been replaced by carbon dioxide, there is nothing left to work with. As a matter of fact, this does spoil the luster; we had examples of that in former days. That is what led to a type of dry-room that has an active air-circulation. Today, we are using anywhere from a 2-min, to a 6-min. air-change to carry away any detrimental gases that might accumulate.

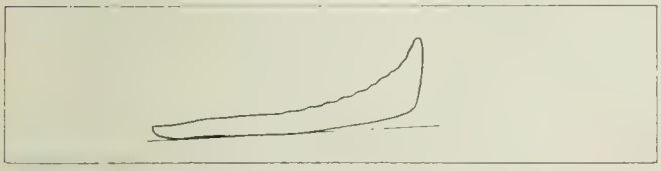
A MEMBER:—Then wherein lies the consistency of reintroducing the air to the blower?

MR. LIPPERT:—The life of the air is renewed in the air-washer. When air in the quantities delivered by the kind of drying equipment under discussion has passed over the body it is not necessarily exhausted. It can be put through the air-washer with safety and its humidity and freshness built up, particularly if an equal volume of fresh air is introduced at the same time. It may not be entirely consistent to use the air again but, since this does no harm and saves operating expense, it would be foolish to do otherwise. In the old type of drying it was customary to close the room tight, use the air it contained until it was all worked out and then throw it away. We recirculate a portion of the air before it is devitalized. We use as much as is compatible with perfect safety. A certain amount of oxygen is required to perform the oxidation and, if sufficient time is allowed, the results are satisfactory. The principal motive today is to produce as much within as little space as possible. If it is a fact that such results as I have indicated can be produced in one-tenth of the time in which they were produced formerly, without ruining the product, is it not better to provide the equipment that will establish such a condition and thus guard against the uncertainty of normal air-drying?

FUEL RESEARCH DEVELOPMENTS

(*Concluded from page* 296)





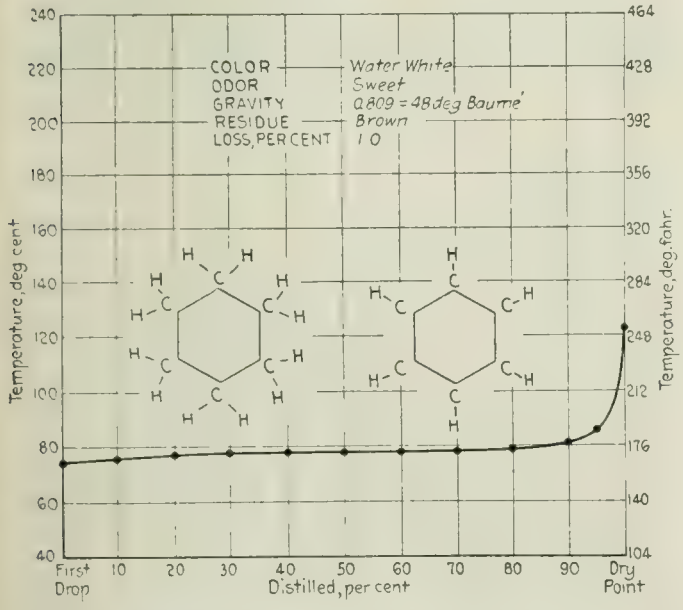
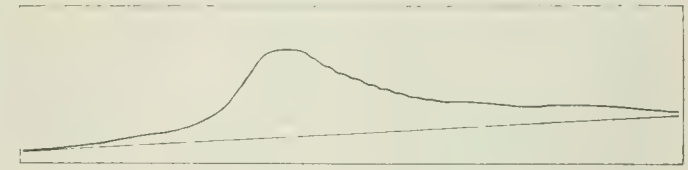
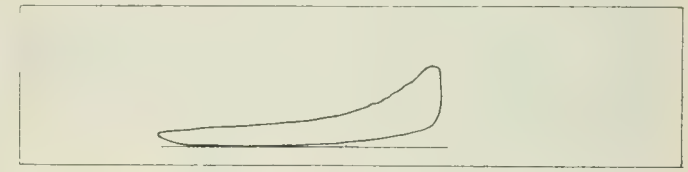


FIG. 14—FUEL STUDY OF A MIXTURE COMPOSED OF 80 PER CENT CYCLOHEXANE AND 20 PER CENT BENZOL

work to overcome the attendant difficulties. When we break a crankshaft, we take it to the chemical laboratory, have it analyzed, see whether the chemical composition is right and then trace the heat-treating. We should apply the same study and method to the fuel theory that we have applied to the heat-treating theory.

The indicator cards produced by the different fuels are shown in Figs. 7 to 15. Fig. 7 shows the distillation curve of a fuel as determined by the standard method given by the Bureau of Mines. The distillation curve shows the temperature at which a fuel evaporates. It is a function of the size of the molecule and is only an easy





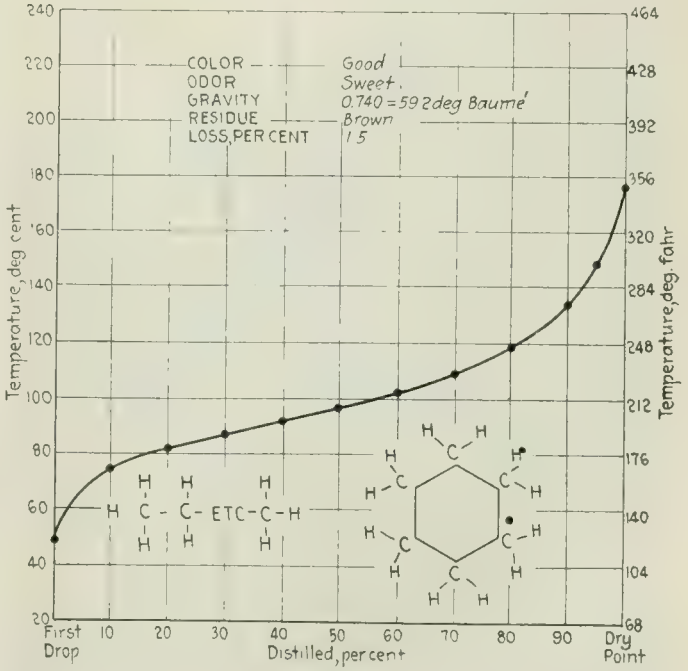


FIG. 15—FUEL STUDY OF A GASOLINE OBTAINED FROM A CALIFORNIA CRUDE OIL

way of weighing the molecule. Fig. 7 shows also the pressure-time and pressure-volume indicator cards produced by commercial denatured alcohol. When the alcohol goes off with a very little increase in temperature, it simply means that all of the alcohol molecules are of about the same size. We know that when water reaches 212 deg. fahr. it all goes off without an increase in temperature. That is simply a proof of the fact that the molecules are the same size. The upper card shows the type of curve produced when alcohol burns. The lower card shows the pressure-volume curve.

Fig. 8 is a fuel study of sulphuric ether. It is shown to demonstrate that volatility has nothing whatever to do with knocking. It is a very volatile fluid and a beautiful knocker. It has a very low vapor-point, and this shows that specific gravity has nothing to do with the knock.

Fig. 9 is a study of butyl alcohol. It does not have so good a distillation curve as sulphuric ether, but has the same general explosion and gives no detonation.

Fig. 10 shows a carbon bisulphide study. It exhibits very bad preignition, so that the pressure-volume loop, where it comes back on itself practically, can be seen; yet it produces absolutely no knock.

Fig. 11 shows kerosene, at the left, and commercial gasoline, at the right, from Pennsylvania crude. We can see what is meant by abnormal combustion. The distillation curve starts way up.

Fig. 12 is a study of fuel oil. It is a little farther down the scale. Fig. 13 shows benzol. The curve comes up and flattens off nicely. That flat top is the thing that we must get with gasoline. Fig. 14 shows a mixture of 80 per cent of cyclohexane and 20 per cent of benzol. Fig. 15 shows California gasoline.

Table 1 gives the excess energy liberated during detonation. We took a cubical content of fuel mixture that would give ether a value of 1000, paraffin 860, olefin 805, naphthaline 780, aromatics 545 and alcohol 620. The anti-knock substances are simply things that, put into the fuel, will absorb that excess energy.

TABLE 1—ENERGY LIBERATED DURING DETONATION

Fuels	Excess Energy Liberated During Detonation
Ethers	1,000
Paraffins	860
Olefins	805
Naphthines	780
Aromatics	545
Alcohols	620

Future Objectives

I hope to interest automotive engineers enough in knowing that there is a road by which physical chemistry, thermo-chemistry and the simple laws of elementary physics can help take this apparently complex combustion problem and analyze it so that we can understand what happens and work better with the people who are producing our fuels to find out whether they can better adapt or better fit them to the machines in which they are to be used. That is the viewpoint that automotive engineers should have. These matters are important. The fuel economy of our motor vehicles must be improved. We must burn less fuel per car-mile. We must reduce the mechanical friction. If we should use measuring apparatus, we might find that it takes more power to turn the engine than it does to run the automobile. The engine frictions are excessive. Engine friction today is one of the biggest problems we have; it can do much to prevent the attaining of adequate fuel economy. A better understanding of fuel combustion will help us to build better and more economical engines.

The Bureau of Standards is doing much good work. Let us utilize all this and take advantage of the Society meetings as occasions to report progress and assemble our data. It is only by reporting on progress and talking matters over that we will attain the desired results. Each year we find we have progressed somewhat. In any new problem the increment of progress is relatively small. That is true of the growth of any business.

OBITUARIES

Peter Cooper Hewitt, noted scientist and inventor, died at Paris, France, Aug. 25, 1921, from pneumonia, following an operation, aged 60 years. He was born, March 5, 1861, at New York City, and, following his preliminary education, was graduated from the Stevens Institute of Technology, Hoboken, N. J., and from Columbia University, New York City, receiving the degrees of Mechanical Engineer and of Electrical Engineer. In 1903 he received the degree of Doctor of Science from Columbia University and a similar degree from Rutgers College, New Brunswick, N. J., in 1916.

He was a trustee of Cooper Union, founded by his grandfather in New York City, and had an active interest in the affairs of industrial corporations and technical societies. His achievements in the fields of science and invention received extensive public recognition and his untimely removal from such activity constitutes a distinct public loss.

He was appointed a member of the United States Naval Consulting Board in 1915 and was a member of many technical societies and clubs, such as the American Physical Society, the Inventors' Guild, the Institute of Radio Engineers, the American Institute of Electrical Engineers, the Society of Naval Architects and Marine Engineers, and others.

His chief inventions included the mercury vapor electric lamp, the static converter or rectifier used to convert alternating electrical currents into direct currents, the electrical interrupter, the wireless receiver, the telephone relay and electric wave amplifier, and wireless telephone and telegraph apparatus. He was elected to Member grade in the Society, Oct. 18, 1916.

H. P. MacDonald, vice-president of Snead & Co., Jersey City, N. J., died at his summer home in New London, Conn., Aug. 25, 1921, aged 41 years. He was born, May 19, 1880, at Louisville, Ky., and was a resident of Montclair, N. J. He was graduated from the Massachusetts Institute of Technology in 1901 with the degree of Bachelor of Science in Civil Engineering and entered the employ of the Snead company the same year, serving successively as assistant superintendent, general superintendent, chief engineer and vice-president. He held membership in the American Society of Mechanical Engineers, the American Society of Civil Engineers and the American Heat-Treating Society.

Mr. MacDonald was responsible for a number of inventions among which was a series relative to the electrical heat-treating of ferrous and non-ferrous metals through a utilization of internal resistance. This system was used extensively during the war for the heat-treating of steel tubing required in American, English and Italian airplane plants and was described in a paper at the 1919 Summer Meeting. He made also a series of inventions useful in the automotive industry and relating particularly to propeller shafts having flexible fabric joints, as well as in regard to the preheating of gasoline through the use of an electric current. He was elected to Member grade in the Society, March 8, 1919.

Current Standardization Work

AT the September Division meetings several recommendations were approved for submission to the Standards Committee members at the January meeting. The recommendations are not published in their entirety in this issue, as the December issue of THE JOURNAL will contain the complete reports of the Divisions to the Standards Committee. Copies of the recommendations are available, however, and will be sent to Society members upon request.

Division Meetings

A joint meeting of the Steel Roller Chain Committee of the American Society of Mechanical Engineers, the Committee on Sprockets of the American Gear Manufacturers Association and the Chain Division of the Society's Standards Committee was convened in New York City on Oct. 4, the report of a special committee that met on Oct. 3 being presented for consideration. Definite action was taken on sprocket dimensions. The members of the Ball and Roller Bearings Division met on Oct. 11, members of the Subdivisions on Roller Bearings and Thrust Ball-Bearings also attending the meeting. Determinations were made in the matter of shaft and housing fits and tolerances for ball bearings and annular ball bearing tolerances. Other subjects considered were annular ball bearings of the wide type, roller bearings and thrust ball-bearings. The Electrical Equipment Division met in New York City on Oct. 17 in the Engineering Societies Building. Reports were submitted on flexible conduit, spark-plug hoods, generator and starting-motor mountings, magneto mountings, ignition timer-distributor mountings and magnet wire.

Meetings of the Iron and Steel, Lighting, Parts and Fittings, Frames, Axle and Wheels, Passenger Car and Screw-Threads Divisions have been scheduled, as several Subdivision reports are awaiting final Division action.

Automobile Bumper Mountings

At the September meeting of the Parts and Fittings Division a Subdivision report was submitted by F. G. Whittington and E. W. Weaver outlining the reasons for standardizing bumpers, possible methods and conditions. The report follows:

Standardization should be undertaken because

(1) The general need for bumpers is conceded and the demand is increasing owing to insurance companies granting discounts for bumper equipment in issuing collision insurance and to the general desire of the public to add to the appearance of passenger cars

(2) Passenger-car factories are beginning to meet the demand for bumpers, showing that they feel the necessity for such equipment, although the majority of bumpers are mounted by owners

(3) At present the passenger-car builders in general are not providing for accommodating a bumper and as a result means are necessary to permit mounting

(4) The majority of mountings are very unsatisfactory as to both safety and appearance

(5) Standardization can easily be worked out by having close cooperation between passenger-car and bumper manufacturers

Bumpers might be mounted

(1) By bolting directly to the vertical web of the frame channel. This method is not covered by patents

(2) By attaching directly to some special means provided by the passenger-car builder

Of these two methods the first is undoubtedly the better. In using this method, cooperation should be obtained from not only the passenger-car manufacturers but from manufacturers of rebound shock-absorbers as it may be possible to use the rear holding bolt of the bumper bracket for shock-absorbers of this type.

Many manufacturers now provide holes for shock-absorbers, whether or not these are factory equipped. It may be necessary, however, to consider a change in the position of the hole for this type of shock-absorber to accommodate the rear hole of the bumper arm.

Some reasons for favoring the bolted-on type of mounting bumpers are that it

(1) Avoids an unsightly looking fitting required on other types of mounting

(2) Is more rigid than any other type of mounting

(3) Is easier to install

(4) Is less subject to loosening if the bumper receives a severe impact

(5) Avoids infringement of patents

(6) Is the cheapest installation

A hole of 17/32-in. diameter located in the usual position of the first frame-horn rivet would be the logical position for the forward hole in the bumper mounting for the following reasons:

(1) The bumper support should be as near the front of the frame-horn as possible to insure rigidity

(2) A distance of $3\frac{3}{8} \pm \frac{5}{8}$ in. from the first rivet hole of the frame-horn to the spring shackle-bolt is used in 90 per cent of the passenger cars now on the market. On the other 10 per cent a hole could be provided at this distance from the spring shackle-bolt without weakening the frame or interfering with the design

(3) The use of a bolt with a flat head instead of a rivet would not be objectionable in case passenger cars were not equipped with bumpers at the factory and it would make an easy attaching means for the first bolt at least

(4) The height of the first rivet in present practice varies from 17 in. to 22 in. from the ground, with the large majority close to $19\frac{1}{2}$ in. Practically all present-day bumper mountings place the bumper about 20 in. above the ground. Considering the thousands of bumpers now mounted and in use the height could be specified as $19\frac{1}{2} \pm 2\frac{1}{2}$ in. measuring to the center of the bumper

Standardization should not limit the maximum width of the impact surface, but should restrict the minimum to 2 in. These figures relate to front bumpers only.

Considering rear bumpers, it is possible to locate rails 23 in. from the ground, but no lower, with a standard mounting applicable to all passenger cars. A wide impact surface would, however, prevent telescoping even at this height. A loaded car would bring this figure down to possibly 21 in.

A bolted-on type of mounting would require an extra hole in addition to the bolt at the first rivet hole as there would be no shock-absorber holes.

Passenger cars having cantilever, full-elliptic or platform springs should have two holes at the extreme end of the frame about 4 in. apart for the mounting of bumper brackets, of which there will always be special models on account of the wide differences in passenger-car design.

Body Nomenclature

The report of the Subdivision on body nomenclature which was published in the September issue of THE JOURNAL was reviewed at the meeting of the Passenger-Car Body Division held on Sept. 23 and several suggestions that had been received in reference to the report were acted upon. It was felt that there will always be certain special types of custom-

built body differing somewhat from the types covered by the nomenclature proposed, but that such types can be suitably denoted by prefixing the standard names. It was decided to omit the term "town car" as a separate type of body, with the understanding that the word "town" as a prefix should apply to the name of any closed-type body the permanent roof of which does not extend over the driver's seat.

The revised report covers definitions for roadster, touring, sedan, berline, limousine, brougham, sedan-landaulet, berline-landaulet, coupe-landaulet, limousine-landaulet and brougham-landaulet. The complete definitions will be published in the report of the Passenger-Car Body Division in the December issue of THE JOURNAL, together with illustrations for each type.

Bolt and Rivet Specifications

Information covering average dimensions of bolt and rivet heads, obtained by the Bolt, Nut and Rivet Institute, has been submitted to the Standards Committee and will be acted upon at the next meeting of the Screw-Threads Division. The economic value of standardizing bolts and rivets is obvious, but will be realized only through general adoption of standards approved. This means that the standards finally approved by the Society must be in accord with the best engineering practice. Comments and suggestions have been solicited from automotive users and the action to be taken by the Screw-Threads Division will be guided largely by advices received.

Clutch-Bearing Oiler

The suggestion that clutch-bearing oilers should be standardized was discussed at the September meeting of the Transmission Division. Although it was recognized that it is difficult to formulate a standard which would be widely used, owing to the fact that this mechanism depends largely upon individual design, A. A. Gloetzner was appointed a Subdivision of one to investigate the subject.

Clutch Facings

At the meeting of the Transmission Division members held on Sept. 21 the Subdivision report on clutch facings published in the October issue of THE JOURNAL was reviewed. Eighteen sizes of clutch facing for multiple-disc clutches were recommended for adoption and six sizes for single-plate clutches. The final report of the Division will be published in the December issue of THE JOURNAL. It was suggested that the location of the rivets and the rivet sizes should be standardized as this would be of value to clutch and clutch-facing manufacturers and distributers in replacement work. Mr. Bryan, who formulated the original report, was asked to give further consideration to these suggestions and, if feasible, to formulate recommendations.

Circular Shims

The Parts and Fittings Division has recommended that the subject of standardizing circular shims should be tabled indefinitely as the sizes, thicknesses and purposes for which shims are used involve practically all fields of design.

Door-Fit Clearances

The Passenger-Car Body Division has proposed as S. A. E. Recommended Practice that door-fit clearances for all doors other than those of the flush type shall be in accordance with the tolerances specified in the accompanying table

DOOR-FIT CLEARANCES

Location	Clearances, In.
Hinge Side	1/8 ± 1/32
Lock Side	3/16 + 1/16, — 0
Bottom	1/4 + 1/16, — 0
Top	1/8 ± 1/32
Jamb	3/16 + 1/16, — 0
Bead	3/32 + 1/32, — 0

These clearances are for all types of body and are measured from wood-to-wood or metal-to-metal before painting.

The Division also proposed for adoption as S. A. E. Recommended Practice that door-flange widths shall be 5/16 in. on the hinge-pillar side and ½ in. minimum on the lock-pillar side and on the bottom.

Door Handles

At the last meeting of the Passenger-Car Body Division the Subdivision report on door-handle squares, published on page 209 of the September issue of THE JOURNAL was approved, with the additional recommendation that a chamfer of 45 deg. be specified for the end of the externally threaded type. There was considerable discussion with reference to the tolerances specified in the Subdivision report, it being argued that they are too close for commercial practice, but it was decided that they should be retained as they are specified by many large users of 5/16-in. cold-drawn key-stock.

Door Hinges

A Subdivision of the Passenger-Car Body Division has been appointed to formulate a recommendation for the exposed type of malleable-iron or forged door-hinge. It was suggested that the following dimensions would be satisfactory as recommended practice

SUGGESTED DOOR-HINGE DIMENSIONS

Material	Plate Width, In.	Thickness, In.	Screws
Malleable	1¾	3/16	4 No. 10
Iron or Forged	2	1/4	4 No. 12
Pressed Steel	2	1/8	4 No. 12

The Clearance between plates when the hinge is closed shall be 1/16 in. at the exposed end and taper to 1/8 in. at the concealed end.

It was also thought that hinge-pin diameters, hinge offsets and possibly hinge projections could be standardized.

Engine Mufflers

At the meeting of the Engine Division on Sept. 20 a progress report on engine mufflers was submitted by F. M. Seig covering nine sizes of muffler. Mr. Seig stated that a survey of present muffler practice indicates that the 24-in. length is used very extensively and that a standard establishing lengths would be valuable to muffler manufacturers.

In discussing the relation of muffler capacity to the back-pressure it was stated that there is no uniformity in practice. It was thought also that there should be some standard for determining a "silence factor" for mufflers when operating at speeds up to 50 or 60 m.p.h., as above such speeds mufflers cease to function. It was said that experience shows that proper exhaust-port and manifold design will eliminate mechanical engine noises which, when transmitted to the muffler, cause irregular exhaust vibrations.

Engine Numbers

The problem of numbering automobile engines so as to minimize the stealing of automobiles was discussed at the September meeting of the Engine Division. This problem is important from the users' standpoint, and consequently from the builders' standpoint, because insurance companies are willing to make a reduction in theft-insurance premiums of 7½ per cent for a satisfactory means of numbering engines. Several suggestions were discussed, such as inserting an expanding disc in a counterbored hole in the crankcase; casting numbers of an opaque material in the crankcase in such a way that an X-ray photograph of it would show the numbers cast therein; the use of raised numbers; casting a small thin fin on which the number could be stamped on the crankcase so that the fin could be broken off by the dealer and held by the purchaser; and casting on a small thin brass plate with the edges crimped down ⅛ in. and knurled so as to anchor the crimped edges securely in the crankcase.

After considerable discussion it was felt that the most satisfactory method of numbering engines is to stamp script numbers ¼ in. high and 1/32 in. deep between two parallel vertical ribs ¼ in. wide, ⅛ in. high, 3 in. long and 3 in. apart, the surface of the casting between the ribs being left as cast.

In stamping the numbers the same numbers would be stamped at the top and at the bottom of the 3-in. square space. In case of an error being made in stamping the top or bottom numbers, additional numbers would be stamped directly under or above the number, the numbers containing errors being cancelled by stamping a horizontal line through them. In this way two correct unmutilated numbers would appear on each engine.

It was the consensus of opinion of the Division members, after studying the ideas submitted, that this method of numbering is the most practical and effective means of preventing numbers being changed, especially as it requires no additional parts, tools or operations.

Engine Torques

The members of the Engine Division have decided that it is not feasible to standardize engine torques, owing to the fact that differences in mechanical conditions require entirely different cranking torques.

Fan-Belts and Pulleys

The Engine Subdivision on Fan Belts and Pulleys submitted a report at the last Engine Division meeting covering fan diameters, projected blade-widths and pulley widths for flat fan-belts, depths of pulley groove, belt widths, fan diameters and projected blade-widths for vee fan-belts. An included angle of 38 deg. was recommended for vee-belt pulleys.

Flexible Conduit

The Subdivision on Flexible Conduit submitted two reports for consideration, covering non-metallic flexible conduit and metallic flexible conduit for electrical wiring. These were acted upon at the meeting of the Division held on Oct. 17.

Flywheel Housings

At the September meeting of the Engine Division it was brought out that the present clearance space for crankshaft flywheel bolts and nuts specified in the S. A. E. Standard for flywheel housings is not suitable for small engines having two crankshaft bearings and a large crankshaft flange, and that a clearance should be specified for use when United States Standard, instead of S. A. E. Standard, bolts and nuts are used. After an interesting discussion it was felt that a recommendation should be formulated covering clearance spaces in proportion to the size of the housings instead of but one clearance space for all sizes.

Lock-Washers

The Subdivision report on lock-washers submitted by E. W. Hart for the approval of the members of the Parts and Fittings Division, published on page 119 of the August issue of The Journal, was approved at the September meeting with the following changes

(1) ¼ instead of 1¼-in. dimension for *A* for the 1⅛-in. size S. A. E. Standard bolt
(2) Omitting the lock washer for the No. 10 or 3/16-in. S. A. E. Standard bolt
(3) 3/16 x 1/8 instead of 3/16 x 3/32-in. dimensions for the section dimensions of the lock-washer for the 9/16-in. S. A. E. Standard bolt

Oil-Drain Plugs

Careful consideration was given at the Sept. 20 meeting of the Engine Division to the advisability of designing engines with a conveniently located oil-drain to permit emptying the oil from the crankcase as easily as it was poured into it. It was the general opinion that the oil-drain is so dependent upon individual design and relatively unimportant in connection with interchangeability that no definite type should be standardized. It was thought, however, that a recommendation could be made which would indicate that a suitable oil-drain device should be used, having a minimum size hole and located at the lowest part of the oil-pan or lower half of the crankcase.

The Society is to obtain information as to present oil-drain practice in reference to hole size, location, means of operating and suggestions as to how they might be standardized.

Rubber Bushings

When holes are punched in sheet metal for carrying grommets or bushings, particularly when they are made of rubber, it is recommended by the Passenger-Car Body Division that the hole should be necked. In discussing the feasibility and desirability of standardizing bushing dimensions, the members of the Division thought that no great saving would result, as the cost of molds and material involved is low, but it was recommended that the Electrical Equipment Division consider the desirability of establishing standard dimensions in accord with the S. A. E. Standard for insulated cable.

Water-Pipe Flanges

At the Sept. 12 meeting of the Parts and Fittings Division a series of water-pipe flanges was approved for adoption as S. A. E. Recommended Practice. The flange dimensions recommended are in accord with the dimensions recommended by the Radiator Division for radiator-tank outlets and inlets and permit using standard gaskets.

Water-Pumps

As the design of water and oil-pumps varies to a very large extent, owing to special requirements such as capacity and fuel consumption, members of the Engine Division have tabled this subject as not being feasible to standardize. It is thought, however, that certain water and oil-pump parts might be standardized to advantage.

Windshield Side-Arms

It has been thought that the Passenger-Car Body Division should formulate a standard for the shanks of windshield side-arms so that body builders can furnish standard holes in the body frames. This matter was discussed at the last meeting of the Division, when it was suggested that the shank diameter should be in odd number sizes and the hole diameter in even number sizes, and that there should be a definite series of lengths and threaded ends. The Society is to obtain information from windshield manufacturers bearing on present practice.

Wire Mesh

At the meeting of the members of the Parts and Fittings Division held in September the standardization of wire mesh was considered feasible. Data will be gathered as to what mesh and corresponding wire sizes are used for oil, air, gasoline and water strainers.

Wiring for Beads

The Passenger-Car Body Division has proposed as S. A. E. Recommended Practice that for engine hoods up to and including 30 in. long top-hinge rods shall be 5/16-in. diameter and side-hinge rods ¼-in. diameter, and that for fenders, aprons and splash-guards the wiring used for beading should be No. 11 Birmingham gage bright basic wire. At the time this recommendation was made it was brought out that many fenders are being made without beadings, but the members of the Division considered that such practice is not in accord with the best engineering construction as it leaves the fender edges sharp.

THE ENGINEERING APPROACH

THE public is apparently beginning to lose faith in short-cuts and political expediency and will more and more demand social and economic readjustments based on a full understanding of all the facts and a thorough-going orientation of all the elements in any given situation. There is clearly discernible a growing sense that somehow the engineering approach is what is needed if ordered progress is to be the watchword for a civilization in the agonizing process of seeking new levels.—M. L. Cooke.

ACTIVITIES OF THE SECTIONS

Sections Calendar

BUFFALO
(Secretary—George H. Pettit, 1569 Jefferson Street, Buffalo)
Nov. 15—Inlet Manifolds by R. W. A. Brewer

CLEVELAND
(Secretary—E. W. Weaver, 5103 Euclid Avenue, Cleveland)

DAYTON
(Secretary—R. B. May, Dayton Engineering Laboratories, Dayton)

DETROIT
(Assistant Secretary—Mrs. B. Brede, 1361 Book Building, Detroit)

INDIANA
(Secretary—B. F. Kelly, Weidely Motors Co., Indianapolis)

METROPOLITAN
(Secretary—F. E. McKone, 347 Madison Avenue, New York City)
Nov. 18—Chassis Lubrication by C. T. Myers

MID-WEST
(Secretary—Taliaferro Milton, 140 South Dearborn Street, Chicago)

MINNEAPOLIS
(Secretary—C. T. Stevens, 13 South Ninth Street, Minneapolis)

NEW ENGLAND
(Secretary—H. E. Morton, B. F. Sturtevant Co., Hyde Park, Boston)
Nov. 11—Ignition Meeting at Springfield

PENNSYLVANIA
(Secretary—T. F. Cullen, Chilton, Co., Market and 49th Streets, Philadelphia)
Nov. 22—Fuel and Diesel Engine Meeting. Speakers—H. L. Horning and A. K. Brumbaugh

WASHINGTON
(Treasurer and Acting Secretary—C. H. Young, 210 Riggs Building, Washington)

THIRTY members of the Mid-West Section met at dinner on Oct. 7. O. B. Zimmerman, chairman of the Section's Paper Committee, reported on the plans for the season's activities. The program will consist of a series of meetings on the fundamental theories of thermodynamics and a study of the laws of heat, a knowledge of which is essential for the designing of internal-combustion engines. Prof. Daniel Roesch addressed the Section members at their meeting held on Oct. 31.

Thomas Midgley, Jr., gave a talk on liquid fuel reserves at the Oct. 13 meeting of the Indiana Section.

The Cleveland Section held its first fall meeting on Oct. 21. The Council of the Society met in Cleveland on the same day and a number of the officers of the Society and members of the Council took advantage of the opportunity to attend the Section meeting in the evening. President Beecroft spoke very interestingly and earnestly on the standardization work of the Society. H. A. Schwartz gave an account of a series of tests on the physical properties of malleable cast iron.

The Detroit Section opened its season on September 30 with an address by Dr. H. C. Dickinson, manager of the Research Department of the Society. An added feature of the program was the showing of moving pictures of the recent aerial bombing operations against battleships. Past-President Coffin gave an address on the necessity of enabling Federal legislation on aircraft regulations.

C. H. Metz presented some automotive historical notes and personal reminiscences at the Oct. 13 session of the New England Section. Prof. William J. Drisko discussed automobile head-lamp illumination and the Massachusetts regulations thereon. At the next meeting of the Section, scheduled for Nov. 11 at Springfield, the subject will be ignition.

The Metropolitan Section will listen to C. T. Myers and others discuss the subject of chassis lubrication at a meeting on Nov. 17. Both approved methods and recent developments will be considered, including self-lubricating substitutes for spring-shackles.

The members of the Pennsylvania Section will add to their knowledge of internal-combustion engine fuel and how to use it, through papers by H. L. Horning and A. K. Brumbaugh which will be given at the Section meeting scheduled for Nov. 22.

The Minneapolis Section reports a rearrangement of the order of presentation of the papers for its coming meetings. It will devote the season to tractor subjects in accordance with the original plan. Meetings are scheduled for the first Wednesday of each month, at the Builders' Exchange.

Robert W. A. Brewer will give a paper on inlet manifolds before the Buffalo Section on Nov. 15.

CALCIUM CHLORIDE FOR ROADS

IF one takes a small amount of calcium chloride and places it on an ash-tray or paper-weight, one will observe the rapidity with which it attracts moisture from the air, each granule turning to a drop of water. This is the effect calcium chloride has upon a road. It has none of the detrimental properties of oil and no effect upon tires or clothing, nor is it tracked from the road onto the sidewalks and into the home. It is readily applied with an ordinary lime or fertilizer sower.

This year the Michigan Highway Commission contracted for 6000 tons, to be used on trunk-line gravel roads. The practice followed is to apply calcium chloride on gravel roads in the spring, just as soon as they have dried out and been graded or scarified. The second application is usually made in August. Satisfactory results, as a rule, can be obtained with two applications, but on very heavily traveled roads three applications may be necessary. The material has an accumulative effect; that is, a road treated one year will not require as heavy an application the second year, unless it has been resurfaced. An 18-ft. gravel road requires about 8 tons per mile for a treatment. The cost is approximately $200 per mile applied, which is about one-half of the cost of oil applied.

Connecticut is a heavy user and the Highway Departments of Wisconsin and Minnesota have become sufficiently interested in calcium chloride to purchase trial cars. The Michigan Highway Department believes calcium chloride to be the greatest road-saver to date, considered from all angles. The road surface is held firmly and compact, thereby reducing the frequency of resurfacing with gravel. Grand Rapids, Mich., has this year purchased and applied 800 tons within the city limits and completely displaced its sprinkling equipment. Ann Arbor, Mich., has done likewise and a great many smaller cities have applied the material to their main streets. It should not be applied to a road that has been treated with oil, unless the road is scarified or resurfaced. This is because oil makes the road waterproof and calcium chloride will not function on a waterproof road. If a road has several inches of dust on it, this must first be scraped off or the application delayed until a rain packs it down.—The Timken.

Applicants *Qualified*

The following applicants have qualified for admission to the Society between Sept. 10 and Oct. 10, 1921. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

ASIRE, HORACE W. (M) research engineer, electrical department, General Motors Research Corporation, *Dayton, Ohio.*

BOYNE, WILLIAM KENNEDY (M) Newfield Avenue. R. F. D. 30, *Stamford, Conn.*

BRADLEY, JOHN J., JR. (J) Lincoln Motor Car Co., *Detroit,* (mail) 1404 East Jefferson Avenue.

CALKINS, ADDISON N. (M) superintendent, Electric Wheel Co, *Quincy, Ill.,* (mail) 2334 Maine Street.

CARPENTER, FIRST-LIEUT. CHARLES L. (A) *Fort Crook, Neb.*

CARPENTER, MANSON C. (A) sales engineer, Holley Carbureter Co. *Detroit,* (mail) 323 Tuxedo Avenue, *Highland Park, Mich.*

CLERK, SIR DUGALD (F M) civil engineer, National Gas Engine Co., Ltd., Ashton-under-Lyne, England, (mail) 57-58 Lincoln's Inn Fields, *London, W.C.2.*

COLBURN, HERBERT C. (M) Ajax Mine, *Victor, Col.* (mail) Box 229.

CORSON, BOLTON L. (M) engineer, H. H. Franklin Mfg. Co., *Syracuse, N. Y.,* (mail) University Club.

DOE, THOMAS B. (M) vice-president and general manager, United States Cartridge Co., *Lowell, Mass.*

DORIOT, GEORGES F. (J) Doriot Flandrin Parant, Denis, Courbevoie, Seine, France, (mail) 14 Story Street, *Cambridge, Mass.*

DUFFECK, FRANK W. (A) proprietor, Electric Power Maintenance Co., 1101 Monroe Street, *Toledo.*

ERSKINE, JAMES E. (A) chief engineer, Perfection Engineering Products Corporation, 707 East Bay Street, *Jacksonville, Fla.*

FAGAN, XEN (A) general manager Diamond branch, Rome Wire Co., 56 Clyde Avenue, *Buffalo, N. Y.*

FISCHBECK, HENRY J. (M) foreman of heat-treating department, Wright Aeronautical Corporation, Paterson, N. J., (mail) 137 22nd Street, *Irvington, N. J.*

FITZ GERALD, MAJOR M. L. (A) Maxwell Motor Co. of Canada, Ltd., *Windsor, Ont., Canada.*

FREDERICKS, ELMER VICTOR (A) field manager, Self Seating Valve Co., *Chicago,* (mail) 2021 North Spaulding Avenue.

GEARHART, MAJOR GUY L. (S M) Air Service, McCook Field, *Dayton, Ohio.*

GIBSON, ALLEN W. (A) special representative, Prest-O-Lite Co., Inc., New York City, (mail) 132 23rd Street, *Elmhurst, N. Y.*

GINSBERG, SAMUEL (A) partner, Ginsberg Motor Co., 288 St. Catherine Street, West, *Montreal, Canada.*

HEINES, CHRISTIAN F., SR. (M) president, Big Farmer Corporation, *Fort Madison, Iowa* (mail) 719 Fifth Avenue.

HERON, S. D. (S M) aeronautical mechanical engineer, engineering division, Air Service, McCook Field, *Dayton, Ohio,* (mail) 212 West Monument Avenue.

HOBART, JOHN P., JR. (J) draftsman, Union Gas & Electric Co., *Cincinnati,* (mail) 2419 Salutaris Avenue.

HOOVEN, ALBERT M. (A) secretary and treasurer, Meteor Motors Corporation, Philadelphia, (mail) 25 North Wycombe Avenue, *Lansdowne, Pa.*

INSLEY, ROBERT (J) aeronautical mechanical engineer, engineering division, Air Service, McCook Field, *Dayton, Ohio,* (mail) Powerplant laboratory, McCook Field.

JARROW, HARRY W. (A) Western manager, American Felt Co., 325 South Market Street, *Chicago.*

JOHNSON, FRED V. (M) consulting engineer, Avery Co., *Peoria, Ill.*

JOHNSON, JOHN E. (M) assistant chief draftsman, Reo Motor Car Co., *Lansing, Mich.,* (mail) 1319 West Hillsdale Street.

KERSHAW, LEONARD F. (J) draftsman, Fox Motor Car Co., *Philadelphia,* (mail) 1233 West Hazzard Street.

KING, KENNETH J. (E S) student, University of Wisconsin, *Madison, Wis.* (mail) 927 West Dayton Street.

LAVERY, LORNE F. (J) engineering draftsman, Detroit office, New Departure Mfg. Co., Bristol, Conn., (mail) 1564 Pine Street, *Detroit.*

LEVENE, BERNARD N. (A) vice-president and service manager, Levene Motor Co., *Philadelphia,* (mail) 908 Rockland Street.

LOCKWOOD, F. R. (M) chief engineer, A. J. Detlaff Co., Inc., *Detroit,* (mail) 3766 West Philadelphia Avenue.

LOVE, HORACE (A) H. H. Franklin Mfg. Co., *Syracuse, N. Y.*

MACLEAN, ALLEN D. (J) assistant chief engineer, New Departure Mfg. Co., *Bristol, Conn.,* (mail) 115 Federal Street.

MCGRATH, JOHN (A) assistant treasurer, Eberhardt Mfg. Co., *Cleveland,* (mail) 2131 Adelbert Road.

MCILHINEY, DONALD W. (J) *Great Neck, N. Y.*

MARSHALL, J. F. (A) territory manager of sales, American Felt Co., 1 Greenwood Building, *Cincinnati.*

MARSHALL, LEWIS C. (A) president, Pressure Proof Piston Ring Co., 107 Massachusetts Avenue, *Boston, Mass.*

MAYNARD, H. E. (M) Maxwell Motor Corporation, *Detroit.*

MILLER, EDWARD J. (M) chief draftsman, Allen Motor Co., *Columbus, Ohio,* (mail) 962 Delaware Avenue.

MITCHELL, ALBERT F. (S M) automotive engineer, tank, tractor and trailer division, Ordnance Department, *Washington,* (mail) 2109 F Street, N.W.

MOTTINGER, BYRON T. (M) chief engineer, Quaker City Rubber Co., Philadelphia, (mail) 1123 Harrison Street, *Frankford, Philadelphia.*

PARKER, JESS (A) chief inspector, Jordon Motor Car Co., *Cleveland,* (mail), 1848 Colonade Road, Colonial Heights.

PARSONS, J. B. (M) engineer, storage battery division, Prest-O-Lite Co. of Canada, Ltd., *Toronto, Ont., Canada.*

PIERCE, EDWARD M. (S M) engineering division, Air Service, McCook Field, *Dayton, Ohio,* (mail) 11 Calvert Apartments.

PROSPERI, A. G. (A) sales engineer, Oakland Motor Car Co., *Atlanta, Ga.,* (mail) Apartment A-12, Wyndham Courts.

RICE, JOHN H. (J) mechanical draftsman, American LaFrance Fire Engine Co., Inc., 101 LaFrance Street, *Elmira, N. Y.*

ROBIE, THEODORE M. (M) New York service engineer, Fairbanks, Morse & Co., Chicago, (mail) Box 605, *Oyster Bay, N. Y.*

ROUDENBUSH, ELMER F. (A) truck designer and checker, Stewart Motor Corporation, *Buffalo, N. Y.,* (mail) 38 Northumberland Street.

RUPP, JOHN L. (M) manager of manufacturers sales, Westinghouse Union Battery Co., *Swissvale, Pa.*

SCHEEL, HERBERT (A) president, Scheel Motors Co., St. Louis, (mail) 7449 Gayola Place, *Maplewood, Mo.*

SEBRING, JOSEPH L. (A) assistant manager and director of sales, Miles Piston Ring Co., 5353 South State Street, *Chicago.*

SHIPLEY, MILLARD J. (A) tractor instructor, Michigan State Auto School, 3729 Woodward Avenue, *Detroit.*

SHRUM, A. T. (J) chief draftsman, Walker Vehicle Co., State and 87th Streets, *Chicago.*

SMITH, OSCAR A. (M) superintendent, Coit plant, National Acme Co., *Cleveland.*

SMITH, ROY D. (J) assistant chief engineer, Front Drive Motor Co., *Kansas City, Mo.,* (mail) 3023 Forest Avenue.

STURGIS, HARRY L. (A) assistant superintendent, Locomobile Co., New York City, (mail) 503 West 174th Street.

TAYLOR, LOUIS E. (A) mechanical production department, Brewster & Co., Long Island City, N. Y., (mail) 108 Church Street, *West Haven, Conn.*

WALKER, CLARENCE S. (M) 452 Ellicott Square, *Buffalo, N. Y.*

WAMPLER, HOMER H. (A) owner and manager, Dayton Automotive Specialty Co., 310 East 2nd Street, *Dayton, Ohio.*

WARE, MARSDEN (J) mechanical engineer, National Advisory Committee for Aeronautics, Langley Field, *Hampton, Va.*

WILKINS, HAROLD S. (M) managing engineer, lighting plant division, H. C. Dodge, Inc., Boston, (mail) 98 Central Street, *Somerville, Mass.*

WILSON, ROBERT E. (M) director of research, Research Laboratory of Applied Chemistry, Massachusetts Institute of Technology, *Cambridge* 39, *Mass.*

WOOD, JOHN M. (J) tool designer, Stout Engineering Laboratories 4434 Seyburn Avenue, *Detroit.*

YAGLOGLOU, C. P. (J) mechanical engineer, American Society of Heating and Ventilating Engineers, Bureau of Mines Experiment Station, *Pittsburgh.*

Applicants *for* Membership

The applications for membership received between Sept 21 and Oct. 15, 1921, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

BARCLAY, ERIC, sales manager and technical advisor, Teal & Co., Inc., *Manila, P. I.*

BARROW, ARTHUR T., general manager, Nattrass & Harris Motor Co., Ltd., *Wellington, N. Z.*

BOLGIANO, JOHN F., chief draftsman, transportation, balloon and airship section, Air Service, McCook Field, *Dayton, Ohio.*

BOSWERTH, ALVAH H., vice-president and chief designing engineer, Colador Engineering Corporation, *Long Island City, N. Y.*

BURNELL, E., assistant to president, Overman Cushion Tire Co., *New York City.*

CHASE, RUSSELL D., manager, General Motor Repair & Mfg. Co., *Milwaukee.*

CLARKE, LOUIS E., sales manager, bearing and die casting departments, Hoyt Metal Co., Boatmen's Bank Building, *St. Louis.*

COBURN, HAL H., supervisor of shops, Wellesley Public Schools, *Wellesley, Mass.*

CONNORS, WALTER WILLIAM, engineer, 12 Oakwood Place, *Elizabeth, N. J.*

CURTIS, WILLIAM G., master mechanic, House & Meyers, Inc., *Los Angeles, Cal.*

DAYTON, JOHN C., engineer and manager, Wallace and Granite Streets, *Harrisburg, Pa.*

ECKMAN, NORMAN H., vice-president and general manager, Center Fed Spring Insert Sales Co., *Wilkes-Barre, Pa.*

EMERSON, L. A., head of automotive department, Dunwoody Institute, *Minneapolis.*

EVANS, BOB G. N., secretary, Landman-Griffith Co., *Toledo, Ohio.*

FARQUHARSON, F. B., student, University of Washington, *Seattle, Wash.*

FOSTER, ERNEST H., vice-president, Power Specialty Co., *Dongan Hills, Staten Island, N. Y.*

FRASER, WILLIAM R., service manager, Henry W. Peabody & Co., *Buenos Aires, Argentina, South America.*

GUSTAFSON, HUGO H., chief draftsman, Master Truck Co., *Chicago.*

HALDAR, S. N., automotive student, 90 Sibley Street, *Detroit.*

HANOVER, H. T., president and general manager, Apex Motor Corporation, *Ypsilanti, Mich.*

HAYES, HAROLD W., division engineer, Dodge Bros., *Detroit.*

JARDINE, HENRY, service manager, Standard Steel Motor Car Co., *Boston.*

KEIM, BYRON L., consulting engineer, Automotive Parts Co., *Pittsburgh.*

KLINE, CHARLES W., assistant body engineer, Milburn Wagon Co., *Toledo, Ohio.*

KUHNE, GUS A., garageman, Gus A. Kuhne, *Detroit.*

LENNOX, FRANK H., assistant manager and sales manager, Hoover Steel Ball Co., *Ann Arbor, Mich.*

MCGREW, M. L., rail-car department, International Motor Co., 25 Broadway, *New York City.*

MCKNIGHT, CHARLES, JR., works manager, Carbon Steel Co., *Pittsburgh.*

MICHAELS, CHARLES, president, Michaels & Monroe, *New York City.*

MIKI, KICHIHEI, military engineer, Japanese Army, *Tokyo, Japan.*

MILLER, HOWARD A., junior partner, Automotive Service Co., *Rochester, N. Y.*

NEELANS, HAROLD G., student, University of Michigan, *Ann Arbor, Mich.*

O'CONNOR, THOMAS A., service manager, Western Motors Co., *Los Angeles, Cal.*

PACKER, A. HERBERT, instructor, ignition department, Ambu Institute, 2632 Prairie Avenue, *Chicago.*

PATTERSON, C. E., works manager, Athey Tractor Co., 5631 West 65th Street, *Chicago.*

PEAVEY, CLARENCE W., instructor technical and practical automobile repair, Main Avenue High School, *San Antonio, Tex.*

RAWLINS, EDWARD B., draftsman, C. & G. Cooper Co., *Mt. Vernon, Ohio.*

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SHAW, STILLMAN, consulting engineer, 60 Prospect Street, *Hartford, Conn.*

SOCIETE ANONYME ADOLPHE SAURER, *Arbon, Switzerland.*

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TILLINGHAST, CAPT. T. E., engineering division, Air Service, McCook Field, *Dayton, Ohio.*

UNDERWOOD, ARTHUR J., student, University of Michigan, *Ann Arbor, Mich.*

VANE, C. A., general counsel, National Automobile Dealers' Association, *St. Louis.*

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THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

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The Foremost Economic Force in the Automobile Industry

THE accruing benefits in dollars and cents of the 300 established Standards and Recommended Practices of the Society of Automotive Engineers are astonishing in amount. In view of the inestimable prospective value to be attributed to them, and in appreciation of the responsibility resting on the Society at this time of economic pressure, this issue of THE JOURNAL is devoted largely to the purpose of bringing home the necessity for intelligent study and support of standardization as a prime eradicator of waste effort and expense.

A predominating number of the members of the Society have understood for years the basic necessity of automotive engineering standardization. There has been, however, some lack of comprehension of the extent and magnitude of the money-saving effected by it and of the clear need for extending the work in scope and intensity.

The actual work of the American Automobile Standards movement was started by the engineering section of the industry. Only the engineers could initiate such work in a concrete constructive way, and their continued support, based on strong conviction, was essential to the success of the plan. It is obvious, as it has been all along, that the full force and advantage of attainable simplification and economy in the methods of design, production and use of automotive apparatus are not securable without the whole-hearted attention and cooperation of the executives of the industry.

The work has now reached a stage where a unified movement all along the line, in which the National Automobile Chamber of Commerce and the Motor & Accessory Manufacturers' Association will take a more active part than heretofore, is in prospect. All sound work must be based upon proper test over a sufficiently long period. Pioneering is a thing apart and its fruits must stand on their merits for inevitable though delayed recognition. The success that has been attained by S.A.E. Standardization would have been impossible without constant and ever-increasing cooperation of a remarkably loyal nature from the industry in general. These facts, as well as many other salient features of the work, are made plain by statements of well qualified men in this special issue of THE JOURNAL.

Discussion of the industrial conditions and needs involved is in order at this time of the issuance of the 16 Standards Committee Division Reports that are to be considered on Jan. 10 at the Engineering Societies Building, New York City. Every keen student of the industry should scan these closely.

EXECUTIVES' AID ESSENTIAL

The procedure of the Society is based on the patent fact that the engineers alone cannot, even by extraordinary effort, bring about adequate and widespread standardization in actual practice, for the simple reason that the concurrent willing and hearty support of the executives of the industry is requisite. This applies not only to the use of present S.A.E. Standards but to a still greater degree to obtaining a further measure of standardization in every practicable direction. The full benefits of standardization cannot be had in the face of executive opposition. Neither can they be had from the listless acquiescence of any important section of the industry. The matter is primally one of all pulling together. The stake is a big one.

The profits from standardization begin with the

first operation of fabrication of material or part, and increase in amount through the various stages of trade and commerce, until the user of automotive [illegible] is reached. He reaps the greatest [illegible] sistances of all kinds to the sale, [illegible] ntenance of motor vehicles must [illegible] reatly reduced. There is nothing more effective in this connection than rational engineering standardization. Its invariable effect is to enhance quality and decrease cost of product. *Service,* long discussed in many quarters, is yet a largely unsolved problem. Basically, nothing is as necessary to motor-vehicle maintenance as systematic service conducted promptly at costs fair to all concerned. The satisfactory solution of this problem can be greatly hastened by more complete standardization. The greater the use of automotive apparatus, the greater the need for standardization.

Saving in Dollars and Cents

The assignment of a definite value to the saving effected by the use of S.A.E. Standards in the automotive industry is difficult. An analysis of estimates made by 146 engineers and executives of leading companies in the automotive field indicates their opinion to be that this saving amounts to 15 per cent of the total annual retail value of automotive products. If current estimates of $5,000,000,000 be accepted as correct for this annual production value, it will be seen that the saving would amount to $750,000,000. While this figure is staggering and may be disputed, it nevertheless should act as a stimulus for the individual to determine whether full realization from the value of S.A.E. Standards is being obtained by his company.

The saving specified indicates what has been accomplished through the partial adoption in practice of the 300 standards established by the Society. A brief comparison of these standards with the parts and materials that might be standardized will indicate the astounding possible saving ahead. This saving will be realized, however, only at the direction of the company executives. The application of a standard to a design may require a large amount of thought and time on the part of the engineer. It may be easier for him to not incorporate the standard. There may be no immediate return or saving that could be credited to the engineering department. The executives of the company, having primarily the responsibility for the welfare of the company as a whole, can evaluate the cumulative saving in dollars and cents possible during approaching years from the general adoption of standards, and should direct the efforts of the engineering, production and sales departments to this end. This statement is in no sense invidious to the engineer. He has created and will support the standards. It is an economic fact that where the authority is, there responsibility lies. Both are with the executive in last analysis. This is no time to ignore economic facts.

Nature of Standardization

Standardization is the codification of the best current common practice in the specification of materials and certain characteristics of design. It cannot be said that standardization has impeded the progress of automobile design. It has without question been a great aid to its progress. In addition, without S.A.E. Standardization the sales prices of new and used cars could never have been as low as they have been. The same statement applies to all other automotive apparatus. The standards consist of material, design and mounting-dimension specifications for those things that are essential in the present types of vehicle.

As a case in point, the S.A.E. Steel Specifications, established over 15 years ago, since supplemented annually and just now completely revised, constitute one of the greatest achievements of any industry. Their effect has been to reduce the price of steel by a large percentage. These standards eliminated a great many former specifications that were nearly identical, and enabled the steel-maker to develop a business of great magnitude in a relatively few compositions, whereas before he had been trying ineffectually to satisfy too many varying demands. The unguided whim of the designer no longer ruled, and it became possible for the steel producer to carry materials in stock and meet without delay the requisitions of the automotive trade. The use of high-priced branded steel decreased greatly. Much light was thrown on the subject of alloy-steels, this resulting in markedly increased utilization of them, as well as lower prices by reason of the greater volumes and fewer kinds. The automotive manufacturer could purchase S.A.E. Standard material on the open market, instead of having on his hands a large number of special undertakings necessitating the threshing out of many details with each of several producers. He escaped excessive cost by avoiding special fabrication of materials or the special machining of parts, and accomplished a 50-per cent or greater saving in the purchase of relatively small lots. The cost of standardized gages, to mention another example, became less than one-third of that of similar gages made to special requirements. The S.A.E. Screw Standard not only provided a much needed article, but, like many other Society standards, has had a very decided educational effect upon designers and producers. To do the same work it required less material, thereby reducing material cost, as well as the weight, of automotive apparatus considerably.

It must be borne in mind that the automobile business, inaugurated less than a generation ago, introduced almost innumerable engineering, manufac-

turing and industrial problems which demanded and still demand prompt and skilful attention. Engineering is the science of producing with the minimum of waste effort. The Society of Automotive Engineers has been all along a working agency of high efficiency in these circumstances. Useless duplication of sizes of stock parts and unnecessary divergence in specification and design have been eliminated to a large degree. Today, the fact that a manufacturer may be able to produce according to non-standard specifications a very large number of parts at as low cost as he could produce them according to standard specifications, does not obviate the necessity for standardization, because national, not to speak of world-wide, service demands more than the expedient procedure of any one company.

Industrial Solidarity

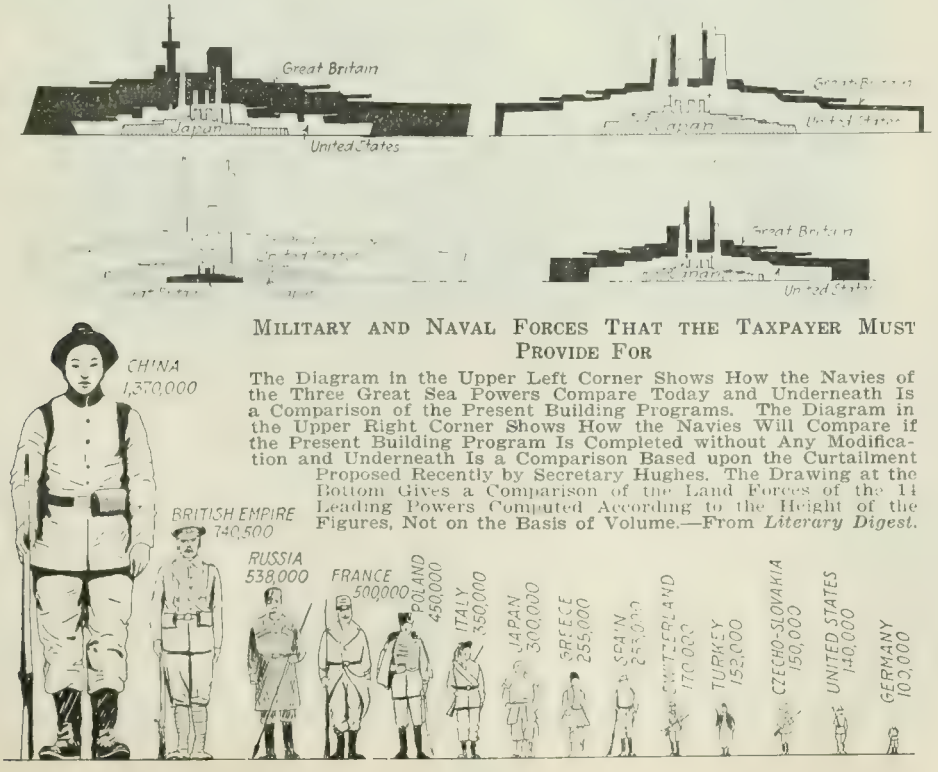
The Society has conducted consistently for many years a headquarters at which the interests of the designer, the buyer, the manufacturer and the motor-car purchaser, invariably discrepant and frequently antagonistic, have been frankly and conclusively discussed and acted upon for the general good. This has contributed greatly to the solidarity and the advancement of the whole automotive industry. It has provided a clearing-house for every pertinent phase of engineering. Such methods result in a rounding-out that makes each individual engineer taking part in the work, no matter how brilliant he may be, more capable than he otherwise would have been. The possibilities of success of any one company are linked indissolubly with the reputation and the prosperity of the whole national industry of which it is a part. There is trade advantage to any company in participating in the establishment and practice of intelligent standardization. Standardization is an economic benefit to any design. It represents always the best proven practice in the art.

Conclusion

The automotive industry is extending its sphere of influence throughout the world. It is laboring strenuously to foster and coordinate as much as possible those phases of automotive production that are so essential to industry and human welfare. In international trade, it is obvious that the need of the maintenance of standardization will make possible the interchangeability of numberless materials, parts and accessories, is inexorable.

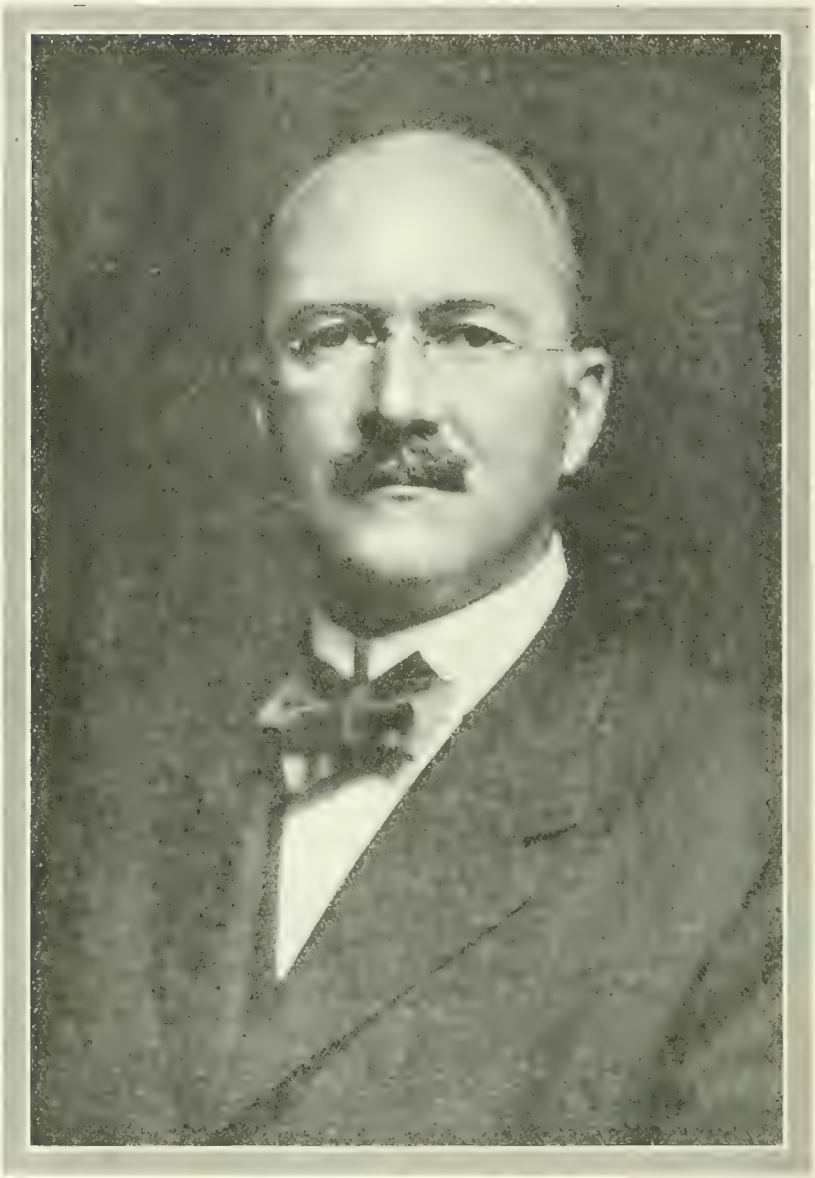
The Society has grown from small beginnings to full stature and maturity. The automotive industry and the public may well be grateful to its founders and to the many splendid men who have served them devotedly and with conspicuous success for over a decade. They have furthered the development of motor-vehicle transportation. They have trained the younger men. They have promulgated economies and modern principles in the fields of automotive manufacture and maintenance. Thus, for its record of practical achievement the Society of Automotive Engineers is unique.

Standardization is the foremost economic force in industry. The words of Secretary Hughes on disarmament apply to it at this time: *What was convenient or highly desirable before is now a matter of vital necessity.*



Military and Naval Forces That the Taxpayer Must Provide For

The Diagram in the Upper Left Corner Shows How the Navies of the Three Great Sea Powers Compare Today and Underneath Is a Comparison of the Present Building Programs. The Diagram in the Upper Right Corner Shows How the Navies Will Compare if the Present Building Program Is Completed without Any Modification and Underneath Is a Comparison Based upon the Curtailment Proposed Recently by Secretary Hughes. The Drawing at the Bottom Gives a Comparison of the Land Forces of the 14 Leading Powers Computed According to the Height of the Figures, Not on the Basis of Volume.—From *Literary Digest.*



A Pioneer in Standardization

THE LAMENTED HENRY SOUTHER, FIRST CHAIRMAN OF THE S.A.E. STANDARDS COMMITTEE.

S. A. E. Standards

Their Value, Recognition and Future Development

By B. B. Bachman[1]

AFTER outlining the manner in which the prophetic vision of the men who organized the S. A. E. Standards work has been fulfilled as regards their faith in the growth of motor-vehicle transportation and the utilization of standardization to promote its development most beneficially, the author alludes to the creation of the Standards Committee by the Society and the carrying forward of its work through 11 years as being monumental in character and follows this with a statement of four special reasons why there is a lack of understanding and in some instances an antipathy to this work.

Discussing each of these reasons with a view to eliminating misunderstanding and antipathy, emphasis is placed upon the duty incumbent upon each member of the Society to follow closely the reports of standardization progress made in The Journal, to criticize, make suggestions and use every effort to prevent any possible stagnation or retrogression in this important work, thus continuing it as a living active influence in the automotive industry.

IN reviewing the history of the Society, we realize that in common with the history of all organizations there are portions that stand out like mountain peaks due to their great importance.

The realization of a few men in the early days of the industry that there was a need for an organization of this character is of course the starting point. However, while there have been and still are numerous problems that can profitably be discussed in the more or less orthodox manner of technical societies, the officers and active members of years past realized that there was need for more than a forum in which opinions and theories could be discussed and contrasted with facts. These men had a vision, almost prophetic, of the future of transportation. They realized that for America to compete in the manufacture of the automobile it was necessary for us to use production methods in which the accurate duplication of similar parts in quantities and by tools and machines rather than by human skill would play a large part.

Purchase and Maintenance

They also saw that to develop this mechanism and solve the many problems that would arise it was desirable that the designers' skill and inventive ability be relieved of all unnecessary detail and concentrated on these other vital things. Likewise, in the field of purchasing materials, the difficulty of comparing values and of obtaining materials in accord with complex and widely varying specifications, such as would exist if these specifications were the result of individual effort, was recognized. In the field of service and maintenance necessary for a complicated mechanism subject to hard usage and unskilled operation, the need for interchangeability was recognized as a means of reducing replacement stocks and minimizing loss of time in waiting for repair parts.

These vital needs pointed the way to one thing, standards. It is inconceivable, in view of the advantages to be gained, even though the difficulties to be encountered be fully recognized, that there should be any lack of acknowledgment on the part of all that the creation of the Standards Committee by the Society and the carrying forward of the work through 11 years is monumental in character. Unfortunately, we must recognize that such is the case, and in recognizing this fact it seems essential to try to realize why there is a lack of understanding of, and, in some instances, antipathy to this work.

Some of the factors that enter into such an analysis and merit consideration are

(1) Ambiguity, and consequent misinterpretation of the meaning of the word standards
(2) Feeling on the part of designers that adherence to standards hampers the expression of individuality in design
(3) The existence of an opinion that standards remove a valuable basis of competition
(4) Lack of support on the part of the executives of the industry

Lack of Understanding

Taking these up in detail, we find that in the first there is considerable misunderstanding of the word standards and what it means. This is probably due to the wide meaning it has in ordinary usage. There are standards of weight and measurement determined with more or less accuracy that vary with the precision of the instruments used to determine them. There are standards of value that fluctuate with changing conditions. To keep in touch with these conditions, we have exchanges, market reports and the like. It is obvious that in these two illustrations we have widely different characteristics; in one there is a frozen condition resistant to change; in the other a fluid condition subject to almost instantaneous response to current conditions.

Neither of these illustrations adequately represents our case. Standards to us can only mean the setting up of logical formulas describing the specifications of materials or the form and dimensions of products based on usage and experience to a very large degree, and dependent for enforcement on the voluntary acceptance of a majority of interested users. Acceptance of this definition indicates that it is difficult to set up standards in defiance of accepted practice or in prophecy of future development; and, furthermore, indicates the fact that the gradual growth of usage, and not the result of a ballot, determines the standard. On the other hand, we are fortunately not confronted, even in our fast-moving industry, with the need of constant revision to suit rapidly changing conditions.

Individuality in Design

The second condition is one of the greatest obstacles in the way of standards, or perhaps it would be better to say has been, for happily a different attitude is being rapidly adopted. The list of standards should be convincing evidence that no sacrifice of individuality need be made that is not perfectly legitimate to gain other more important characteristics. Where is the rational designer who would voluntarily devote his time to creating clevis connections, carbureter flanges, ignition apparatus appli-

[1] M.S.A.E.—Chairman, Standards Committee, Society of Automotive Engineers, and engineer, Autocar Co., Ardmore, Pa.

cations and similar parts, when he can devote it to other more important considerations?

Commercial Competition

eral thought applies to the next factor, ıddition the positive statement can be ad of removing competitive features of standards adds them. The question of ıent stocks at reasonable cost is a vital essential to the growing use of all automotive apparatus. A very large item in the cost is the amount of supplies that must be carried by the dealer to meet requirements. From this consideration alone, though there are many others, the use of standards is justifiable even in domestic markets close to points of production and infinitely more important, even imperative, in foreign markets.

The Attitude of the Executive

This brings us to consideration of the fourth item. It is unfortunate that the beneficent effects of the use of standards is bound up in details that in many instances do not come to the immediate attention of executives. The problems of assigning definite monetary value to the savings effected is difficult for the reason, among others, that these savings are intangible in many cases, start small and slowly, and are cumulative. To illustrate, let us go back 10 years and consider that, due to lack of interchangeability of carbureters and ignition apparatus, major alterations in engine construction were required to change sources of supply in these accessories. What would such a condition be in these later days of large production? Or, let us consider the matter of tires. Memory does not have to be taxed severely to recall the time when a change of either a solid or a pneumatic tire involved a change of wheels as well. Or, take the question of steel specifications. How many times in the past stringent years have the steel-maker and purchaser been enabled to get around a bad corner by the existence of S.A.E. Standard steel specifications?

In these times when economy of manufacture is of supreme importance, it is well worth the time of any executive, no matter how busy, to take a copy of the S.A.E. Handbook, check those standards which are applicable to his needs, find out whether they are being used in his product and if not, learn why.

The Society is a democratic organization. To a greater extent than is possible in any other type of organization, it is free from influences of a commercial character, because it is supported almost entirely by the contributions of individual members and the activities of the organization. We have no means of enforcing standards, nor do we want any of our own, for this is not our province. What we do want is intelligent criticism of our work, and its acceptance and use for what it is worth. This, we believe, is fundamentally the function of trade organizations and executives.

S.A.E. Members' Duty

Now to turn the light inward on ourselves, what should we do in the future to carry this work on successfully? As the Chairman of the Standards Committee for 4 years, I have felt that we must be eternally vigilant to have more and more publicity of the work in progress and consideration and criticism in greater degree by more people to insure the quality of the completed work. I fear that as time goes on, unless we keep ever-mindful of this, our committee work will become humdrum and routine and lacking in vision. I am ever reminded that man to give his best must be spurred forward. No soldier fights who does not hold hatred for his foeman. No one exerts his full strength on a level road. Each member should scan the reports of progress in The Journal and should not hesitate to criticize or suggest. Finally, I believe that the time has come when our Sections should take an active part in the standards work in some way, which is not entirely clear at this time, but which I am confident can be worked out.

In preface, it was stated the standards work was a monument to the Society. Let each member make it his personal business to see to it that this monument does not crumble and decay, but that instead new figures are added to it from year to year so that it may continue a living, active influence in the automotive industry.

AIRCRAFT

WE must have an Army; the best Navy and the best Army our resources will permit and the national defense demands. But without an air force both are helpless. Every advance in the art of war has been accepted reluctantly and only after its superiority over old and worn-out methods has been proven on the field of battle, frequently at the cost of empire, often to the retardment of civilization.

In the last 10 years we have spent about $1,897,000,000 on coast defense, which consists of cannon placed in strategic positions. Cannon have been developed for 500 years, but they cannot hit a military object as well as a bomber can at battle range. Cannon can shoot effectively no more than 10 or 15 miles. They are fixed in position, and the enemy must come to them in order that they may be able to act. It takes as long to get a battery firing properly, that is, about 1 hr., as it takes an airplane to fly a distance of more than 100 miles.

At present there are 21 different bureaus of the Government handling air matters, namely: War Department; Navy Department and Marine Corps; Coast Guard; Aeronautical Board, Washington; Army Air Service Experimental Laboratory, Dayton; Bureau of Entomology, Washington; Bureau of Fisheries, Washington; Bureau of Mines, Washington; Bureau of Standards, Washington; Forest Products Laboratory, Madison, Wis.; Forest Service, Washington; International Aircraft Standards Board; Joint Board, Washington; National Advisory Committee for Aeronautics, Washington; National Research Council, Washington; Navy Aerodynamic Laboratory, Washington; Weather Bureau, Washington and principal cities.

The mapping of the whole country can be made by aircraft in a period of 3 or 4 years at a cost of from one-fourth to one-tenth as great as the cost by any other means. Our forests can be patrolled by airplanes and protected from fire better than in any other way. Farm surveys can be made from the air and help to increase our agricultural production; they will show what crops should be raised, what the forestation should be, where water should be encountered and distributed. Aerial surveys can show where power and electric lines, railroads and roads should be run. Hydrographic work along our coasts, reconnaissance of mine areas and unexplored territories can be successfully carried out. A short time ago it was demonstrated that orchards can be sprayed from planes with fluid for killing insects in the minimum time with great success and at minimum cost. Passengers, express, and mail at present constitute 30 per cent of the business of the railroads. In the not far distant future the air lines will be serious competitors.—C. F. Curry.

The Value of S. A. E. Standards

By E. A. JOHNSTON[1]

IN addition to the adoption of S. A. E. Standards that has prevailed in the automotive industry, the author believes that they have a general application that can be utilized to excellent advantage by many other industries and if the managers in these fields realized fully the great advantage of adopting and using the standards in increasing output, decreasing the cost of equipment and reducing inventories, they would contribute their full support to this important work of the Society.

The benefits of S. A. E. Standards are indicated, specific reference being made to splines, bolts and nuts, steel specifications, heat-treatment, bases for the purchase of parts to eliminate controversy, and carbureter flanges. Quotations are made from *Engineering Production* to show that the importance of such standardization is being realized in England. A leading feature mentioned is that S. A. E. Standards provide a standard of measure against which an entire organization can check to eliminate possible controversies between departments.

IN the minds of those who are familiar with S.A.E. Standards and the great benefit to be derived from the intelligent adoption and use of them, there is no question with reference to their great value to industry. While these standards have been adopted generally in connection with the automotive industry, unfortunately they have not yet been utilized to the best possible advantage in many other industries. If the managers of any industry who are responsible for its successful and profitable operation could be made to realize fully the great advantages in the way of increased output, decrease in cost of equipment and reduction in inventories, and the many other benefits to be obtained by the adoption and use of S.A.E. Standards, they would, without any doubt, be glad to contribute their full quota of assistance to this important work of the Society. But, unfortunately, many of these advantages cannot be measured directly in dollars and cents, and, further, standards are frequently adopted by the engineering departments, automatically going into use and resulting in many savings, unknown to the management.

The adoption of S.A.E. Standards provides a standard of measure for the entire organization to check against, eliminating controversy between engineering, manufacturing and other departments, and effecting great savings of time and confusion and reductions in cost.

The Society's standardization of splines, bolts, nuts and the like has enabled the manufacturers of hobs, broaches, taps, punches, dies and other tool equipment to make these up in sufficient quantity to reduce the cost of such equipment, and has resulted in jobbers and dealers carrying this standard tool equipment in stock, enabling the manufacturer to obtain his requirements quickly, conveniently and at a moderate cost.

In England, the importance of such standardization is only just being realized, as is evidenced by the following paragraphs taken from an article by Harold Ensaw in *Engineering Production.*

> Although each application of the broaching process requires considering on its own merits, there is no reason for the numerous variations in hole sizes that exist today, and it is time that a committee of engineers discussed the matter with the idea of formulating a series of standards for broached holes, or alternatively give publicity to and recommend the adoption of the standards in existence in America.
>
> When an automobile firm designs sliding gears or a differential wheel, the dimensions of the holes are first fixed by the designer, and the broach-making specialist is then called upon to manufacture a broach to produce those dimensions.
>
> This method prevents broaches being manufactured for stock, and is obviously a source of inconvenience that could be easily avoided if the hole dimension and limits were standardized. Broach-makers should adopt standards, and their catalogs should contain the details of them. In addition to greatly assisting the user, it is evident that by such an arrangement a considerable amount of expensive tool-making would be avoided by the broach-maker.
>
> Should such standards be formulated, it would be a simple matter to arrange for suitable milling-cutters to be sold along with the broach. Milling-cutters are invariably required for milling the shafts with which the broached parts assemble, and if made by the broach-maker they are more likely to be suitable for the work, as the same relieving tools could be used as in the case of the milling-cutters that are employed for the broaches.

The S.A.E. Standard steel specifications have permitted the steel-maker to reduce the number of steels fabricated to a quantity making possible economical operation and to carrying the steels in ingots, billets and bars to provide for the requirements of the large or small user quickly, conveniently and at a moderate cost. Further, S.A.E. Standard heat-treatments enable the manufacturer to obtain the desired results accurately and without costly experiments.

In the purchase of parts, when S.A.E. Standards are specified there is immediately established a recognized basis for acceptance or rejection, thereby eliminating all controversy in connection with heat-treatment, material specifications, tolerance, etc.

The development of S.A.E. Standard nuts demonstrated conclusively the advantage of greater thickness with small diameter, as compared with less thickness and large diameter, and nut standards developed along similar lines have saved implement and other manufacturers hundreds of thousands of dollars annually; in fact, more than $500 per day for one manufacturer. As another case of the fundamental importance of the S.A.E. Standards, I cite the carbureters on a large number of trucks shipped to Australia that did not prove satisfactory, making it necessary to supply a different type of carbureter, which procedure was, of course, very much facilitated by virtue of the existence of the S.A.E. Standard carbureter-flange.

While some of the automotive manufacturers have been slow to adopt S.A.E. Standards and many of the implement and other manufacturers do not yet understand adequately the great advantages to be gained by adopting them, nevertheless, on account of the great economies to be obtained, these standards will be generally adopted just as rapidly as the managers of industries can be made to appreciate the great value of such action and in due course these managers will contribute gladly a small part of the saving effected for their companies toward the maintenance and increasing scope of the great S.A.E. Standards work.

[1] M.S.A.E.—Manager, gas power engineering experimental department, International Harvester Co., Chicago.

The United States Council of National Defense

charged by the Congress with the coordination of industries and resources for the national security and welfare, and with the creation of relations which will render possible in time of need the immediate concentration and utilization of the resources of the Nation, hereby

makes grateful acknowledgment of the services

rendered by **The Society of Automotive Engineers** *to its organization, and, through it, to the country, in the course of the Great War.*

Given at Washington, *this twenty-eighth day of June, in the year of our Lord one thousand nine hundred and nineteen.*

The United States Council of National Defense

Secretary of War, Chairman

Secretary of the Navy

Secretary of the Interior

Secretary of Agriculture

Secretary of Commerce

Secretary of Labor

Director of the Council and of the Advisory Commission

THE HELPFULNESS OF THE SOCIETY IN WAR WORK WAS DUE LARGELY TO ITS ACCOMPLISHMENTS IN STANDARDIZATION

Industrial Standardization

By George W. Watson

SPECIAL attention is called to this exposition of the theory and vital value in practice of intelligent standardization in the motor-vehicle engineering field. It was given in an address to the Institution of Automobile Engineers of Great Britain, of which Mr. Watson is president.

The view is expressed that the energetic manner in which the problems of standardization have been tackled, coupled with the loyal cooperation of the American automobile industry in the use of standards, has done more than anything else to bring about the phenomenal development of the motor car in the United States.

In connection with the indifference of the British automobile industry to standardization, Mr. Watson states that, while most of the engineers recognize its benefits, many executive directors have been, and still are, apathetic, and vote money for standardization more in the spirit of "charity" than in appreciation of the fundamentally important manufacturing phase of the question. The sort of apathy to which Mr. Watson refers exists to a deplorable extent in this Country and must be obviated in substantial degree if obtainable results are to be had. It is the only real handicap to American automotive engineering standardization, that is of material importance in placing this economic work in the very high status of effectiveness that it should attain. It is not sufficiently borne in mind that, as Mr. Watson points out, the principle of standardization has existed since the time when exchange and barter were found to be too inconvenient for the development of commerce, a state of things that now exists in Russia. It is the *recognition of a community of interest* in various trades that makes possible the purchasing over the counter of many articles for personal wear or use, not to mention numberless commodities of general utility, at competitive prices. Practices that are unsound will not, and cannot, endure in the automotive or any other industry. The necessity for standardization is more acute in the automotive industry than in almost any other industry.

It remained for an Englishman to produce perhaps the best written interpretation of Abraham Lincoln. The kind of perspective that made this possible has enabled Mr. Watson to deliver a message that calls to mind the adage that a prophet is not without honor save in his own country. What he has to say should be studied with great assiduity by all who are financially interested in or have at heart the design, production and maintenance of automotive apparatus.

Mr. Watson has not, of course, given a comprehensive statement of the basic immutable advantages of automotive engineering standardization, but he has set forth in a vivid convincing manner many salient points and deduced several of the working principles of sane businesslike procedure in the introduction and continued and increasing use of self-propelled vehicles.

WE are all just now going through a most trying period in our history, and many are the suggested remedies for restoring business prosperity. Many of these are political, some social, and others—many others—merely "froth." I do not propose to discuss any of these contentious suggestions, but will confine my remarks to the consideration of a line of action that, if given our personal and collective effort, gives promise of affording a measure of relief to trade in general and to our industry in particular. I refer to standardization, as may be carried out by the British Engineering Standards Association, in collaboration with this Institution, and every other association, body and manufacturer with any interest whatever in automobiles. The Automobile Section of the British Engineering Standards Association during the past year has been reorganized, and there are now good prospects of something tangible being done which should help to bring down the cost of production of both details and completed machines and again put us on a more equal footing with other countries.

British automobile engineering has had a most interesting and varied career. We have had persecution, disappointments, phenomenal developments and now

stagnation, or something akin to it. Britons may always be proud of the fact that their forebears were among the earliest experimenters in mechanical locomotion on the highway, even if they bow their heads in [illegible] at the memory of the acts of stupidity that [illegible] hose early pioneers by requiring their machines [illegible] eceded by a man on foot carrying a red flag. [illegible] t gave to other countries an advantage from [illegible] my mind, they did not profit to the extent that [illegible] :e been expected. None the less, they went steadily ahead, and French engineeers particularly produced vehicles, the performance of which ultimately convinced our slow-moving legislators that they could no longer stem the tide of development. Those of us who have been in the industry continuously since its early days following the emancipation of the motor car can now recall with amusement our early experiences, but the fact remains that Great Britain, after a period of disastrous exploitation by financiers, quickly made headway, overhauled and even surpassed the efforts of French, Italian and German engineers, until, just before the fateful year of 1914, our factories were producing the finest commercial vehicles in the world, while many of our passenger cars were likewise unequaled in other countries.

Except in a small measure, standardization in our industry at that time may be said to have been nonexistent. How different now might be the state of industry had we taken up earlier this important aid to development. By the adoption of standards for many details that were of common application we should have been better prepared to meet any sudden demand for increased transport facilities without calling so largely upon the resources of other countries. The danger of this lack of unification, particularly so far as concerned vehicles for military transport, was recognized by many quite early, and with your permission I will quote extracts from an editorial article which was published in one of the motor papers in September, 1910. In that article we read:

CHAOS IN MECHANICAL TRANSPORT

> Under war conditions, three-quarters of the existing State-owned mechanical transport would be a delusion and a handicap to any commander: each two or three units would need their own load of spares; no important parts are interchangeable throughout any division of wagons or tractors.
>
> What would be thought if this state of affairs held sway in the artillery? What if a gun-carriage or an ammunition wagon had to be abandoned because some little failure must involve long delay while a part was made and fitted on the march? What if it were the exception for any of the gun mountings and breech fittings to be standardized? Yet, in the growing arm of mechanical transport, at least so far, the necessities of the case have been sacrificed to short-sighted considerations which are wrongly supposed to reflect great financial acumen somewhere!
>
> A Standardization Committee should be appointed, and this should be constituted of members of the Mechanical Transport Section of the A. S. C., R. E. officers, and accredited representatives of all *motor manufacturers* who are prepared to produce machines, suitable for military purposes, in accordance with the Army's requirements under an adequate subvention scheme. Although it would not be in the interests of trade that one type of engine, clutch, gearbox, final drive, etc., should be adopted for all internal-combustion-engined machines, the individuality of the designer would not be smothered by the standardization of many detail parts. In the case of vehicles which are propelled by internal-combustion engines, the following are a few of the parts which might well be made to a standard specification, and, if so designed, they would be interchangeable for all makes of vehicles of the internal-combustion-engined class of a given capacity: *starting handle* and spring; diameters of valves, valve springs, cotters, caps, etc.; cam rollers and tappets; clutch (diameter of plates and number of keyways if of disc type, and diameter and angle of faces if of cone type); shape, size and *disposition of the pedals;* shape and *size of radiator* and bonnet; *working positions of change-speed and brake levers; style and position of sprag,* and means for indicating to the driver whether it is in working position; knuckle-joints for steering-gear, also *knuckle-joints for brake gear;* brake-shoes and drums; pitch, type and ratio of chains and chain wheels; *diameters* and widths *of wheels and tires;* sizes of bearing springs and spring-shackles; sizes of strap bolts for spring; hubcaps; *floating bushes for road wheels;* type and position of drawbar; height of carbureter jet and size of screw thread in base of same; *gasoline and water strainers; gasoline-tank filling caps;* and bolts. It might be possible to standardize the diameter of engine cylinders, and, if this were done, one size only would be needed, respectively, for the big-end bushes, gudgeon-pins and bushes, and piston-rings. In the case of steam wagons and tractors, the same process of standardization might be agreed upon.
>
> Were such a Standardization Committee appointed, we are convinced that nothing but good could accrue to the industry, as well as to the mechanical transport undertakings of the Army. The establishment of bases for repairs and renewals could then be placed on a businesslike footing.

AMERICA'S OPPORTUNITY

Shortly after the period to which I have referred a committee was called together, but the personal element was so strong that only a very meager degree of standardization was agreed upon (those items italicized in the above list), and even these were carried into effect by not more than half a dozen makers. One result of this neglect to tackle the question seriously was that we were unable to meet the immense demand when the call was made, and the condition of partial impotence in which the year 1914 found us gave to Americans an advantage which, coupled with the large measure of standardization they had already adopted, enabled their component assemblers to reap such a rich harvest. We are now paying the bill.

WHY WE SHOULD STANDARDIZE

I have selected the subject of Industrial Standardization for my address for three reasons.

First, because, by the standardization of parts we gain the advantage, through interchangeability, of securing to manufacturers uniform standards of materials and dimensions of parts that can commonly be used, and which, being adaptable to many makes and types of machines, can thus be produced in large quantities by specialists at prices that few individual makers could equal were they making similar parts for their own use only. The user benefits to an even greater extent because, once a standard has been adopted and made widely known, it is possible to buy it in almost every town in the country. Common examples of such standardization are the size of screw-threads found on gas burners and fittings and the bayonet-socket lamp-holders for electric lamp bulbs used in house and factory lighting; just think for one moment of the chaotic conditions that would exist among makers, distributors and users of such fittings were no such standards in existence.

Second, the enormous growth of the automobile industry in the United States of America during the past 10 years is in a very large measure due to the adoption of a wide range of standards for materials and details, and even of complete units, with the result that there are now many powerful and successful organizations at work producing complete and interchangeable components. As a direct result there are also a large number of companies that, relieved of the capital cost of installing special machinery for the production of some or all of the components they need, are able to produce completed cars from components purchased outside in numbers unequaled in this country, even in our largest factories. This collective effort and standardization within the automobile industry of the United States is the real reason why such progress has been made over there, and it has enabled prices to be brought down to the point that puts all other countries out of competition. The American home demand is, of course, very large, and the percentage of exported cars compared with the number that is disposed of in the home market is not very great. This large home demand helps our American cousins to get down to rock bottom so far as costs of production are concerned, but I think it is the energetic manner in which the problems of standardization have been tackled, coupled with the loyal cooperation of the automobile industry in the use of such standards, that has done more than anything else to bring about the phenomenal development of the automobile in America.

Third, there never was a period in the history of the British automobile industry when cooperation with a view to the reestablishment of trade, reduction in costs of production and maintenance and the increase of efficiency were more vitally necessary; for these reasons I feel that we ought to leave no avenue unexplored that gives any hope or promise of successful discovery. Hitherto, British industry has been more or less indifferent to the question of standardization, and while most engineers recognize its benefits if carried out in the true spirit of cooperation, many directors have been, and still are, apathetic in the matter; they vote money for standardization more in the spirit of charity donations than as matters of important business. If only they could be brought to realize that standardization is not only possible, but that it is a business proposition and that its successful prosecution would mean increased dividends, the future of our industry would be assured.

Community Interests

The principle of standardization has existed since the time when exchange and barter were found to be too inconvenient for the development of commerce, a state of things that now again exists in Russia, with the difference that in that country almost every article now has a standard value relative to other articles. It is probable that the earliest standards were coins or tokens. Since those days standards of weight and measurement have been established to meet the requirements of various trades and communities, and without them it would be impossible to conduct any business successfully. It is the recognition of a community of interest by manufacturers in certain trades that enables us to purchase over the counter many articles for personal wear or use, not to mention a thousand and one articles of general utility, at competitive prices. I refer to such articles as boots, gloves, safety razors, bicycles and their accessories, cycle tires and similar articles.

Production in large quantities, with special plant, to agreed specifications for materials, dimensions and performance, is the only sure way of cutting down costs. Every standard, however, must be in accordance with the fundamental needs of an industry, and it must have so much to recommend it that neither producer nor user can afford to disregard it. The mere setting up of an intrinsically good standard is not sufficient; if the community interest has been ignored the labor of standardization will have been in vain.

Industrial standardization, or unification as it might more correctly be termed, signifies the interest of producer and consumer. The personal element, which so far in this country has proved to be the most serious obstacle to the establishment of standards, will assume less importance as the advantages of collective effort are recognized, and individuals will be ready to sink their differences of opinion to benefit the many, and incidentally, themselves. This spirit has proved in the United States to have commercial advantages that were not at first apparent, but are now fully recognized by enterprising firms.

Costs of Planning for Fresh Output

Every manufacturer knows only too well the heavy outlay involved in preparing drawings, patterns, dies, jigs and fixtures for the production of a machine, or part, to a specification that may differ only in nonessential details from another specification to which he may be working for another customer. This outlay, of course, has to be borne by the customer. Examples of these needless differences may be found in every factory where specialized articles are made, as, for instance, pistons, piston-rings, spring shackle-pins, etc. It is such details as these that most urgently call for the adoption of standardization. The requirements of the industry must be unified without hampering invention or destroying the individuality of the designer. Any standard should embody the combined experience of an industry so that it represents the best average practice; it can then safely be used as a purchasing specification. Some men argue that nothing should be standardized until we know everything about the subject, while others hold that, from the first, an industry should have provisional standards which may be revised periodically so that they do not limit progress. I think the former line of thought is to be condemned, as there are some things on which our knowledge may always remain incomplete, but that is no excuse for our continuing to interpret in a dozen or more ways such knowledge as we do possess. Let us get together and see each other's viewpoints, then make the best of our present experience and revise the results as progress and requirements dictate. That is the policy of the British Engineering Standards Association. It does not initiate standards, but undertakes the investigation of any subject at the request of an industry. Before commencing work on any one subject, it calls a representative conference of all concerned to make sure that there is a consensus of opinion in favor of such work being carried out. The British Engineering Standards Association has no power to enforce any standard, but given the good will and cooperation of the automobile industry, I am sure that the past and future work of its many sub-committees and panels can only tend to the advancement of the automobile industry in this country, as the work of the Society of Automotive Engineers has done in America.

It has been said that the Society of Automotive Engineers has been too hasty in arriving at many of its standards, and while it must be admitted that very many and frequent revisions are made by them, I suggest that

this only shows the elasticity of the system of tentative standards. They show the average requirements at any particular period, so that makers of components and accessories and suppliers of materials are enabled to [illegible] on an equitable basis.

What Should We Standardize?

[illegible]e well for us to consider for a moment what [illegible] industrial standardization. Do we mean the [illegible]n into one specification and design for each complete car or truck of any given load-capacity, or, what almost amounts to the same thing, the standardization of complete units from which assemblers can turn out finished vehicles or does it mean the careful examination and standardization of details and materials that have common functions to perform, no matter what type of vehicle is under consideration? The former would almost amount to the production of one type of car or truck only, and would practically mean the standardization of the industry's output rather than the standardization of the materials used by the industry. It would put a scotch on progress and bring an end to that much maligned individual, the designer. I have known heads of companies who would welcome the abolition of new designs on the alleged ground that all factory expenses have their origin in the drawing-office; those are the men who will rush the technical staff into production before a design has been digested thoroughly. They will not recognize that alterations can be made on paper at much less cost than in wood or metal.

Does the British automobile industry desire standardization to be carried so far that all motor vehicles, no matter in what factory they are erected, resemble the continuous products of a sausage machine so far as their similarity to each other is concerned? I, personally, do not think so. The vehicle of individual design will always find a market, and the truth of this can be found on the boulevards of Paris or in Fifth Avenue, where there will always be found an appreciable percentage of distinctive British-built cars occupied by discriminating users. We have the choice of assembling, as the Americans do, and commencing a hopeless struggle to compete with them, or of being satisfied to continue to build vehicles that have an individual touch which appeals to a limited market. Probably we shall do best to take the latter course, but even so we cannot hope to succeed unless we apply modern methods of production. We may not be able to build vehicles in such large numbers as to enable us to compete in every market, but we can produce many commonly applicable details in large enough numbers to insure getting down to rock-bottom costs for a large number of details. This can be effected only if we agree, first, what may be included in those "commonly applicable" details, and, second, decide upon their design, materials, dimensions and limits.

A certain number of useful standards were completed before 1914, including the British standard fine thread, while other useful standards have been evolved during the past six years, including the most valuable efforts of the Steels Committee, and the resulting standards for wrought steels. The sizes of magnetos and many other things of special interest to the industry have been dealt with. Much remains to be done, however, and it can only be carried out with the good will and united efforts of all who have any interest in the industry.

Among the first standards on which we require a decision is that of limit gages. This affects all classes of engineering, and it does strike me as remarkable that, after several years of discussion, the committee dealing with this question does not yet feel equal to the responsibility of declaring what should be the size of a 1-in. hole. May it be smaller or larger than the nominal size, or may the tolerance be only above or only below the nominal? The problem, easy enough on paper, is really a very serious one, and its effect varies in different industries. An alternative system, which is really a combination of both unilateral and bilateral systems, has recently been proposed, and if an agreement can be arrived at by the contesting parties it will pave the way for many other standards, as they all, more or less, call for the determination of limits and tolerances.

This vexed question, which our industries alone can decide, as obviously the British Engineering Standards Association cannot impose any standards upon industry, is the biggest problem we have before us, and it must be solved before any new standards can be presented in a form likely to remain unaltered for any considerable period. Tentative standards, however, can be adopted, and there are now before the various subcommittees suggestions for several such standards. These include a number of small fittings, such as gasoline filters, gasoline cocks, drain-cocks, grease-cups, ball-and-socket joint-ends for control rods and lamp brackets, designs of which have been most carefully considered by the Association of British Motor Manufacturers, a committee of which body has put them forward for acceptance by the British Engineering Standards Association. The whole range of automobile standards is being considered by seven subcommittees of the Automobile Section of the British Engineering Standards Association, and if these are all dealt with in the true spirit of cooperation they are bound to have a beneficial effect upon the industry. It is to be hoped that the work of these subcommittees, the constitution of which embodies representatives of this institution, the Association of British Motor Manufacturers, the Society of Motor Manufacturers and Traders, the War Office and other Government Departments and various users' associations, will not be hampered by attempts to impose personal opinions as distinct from collective experience. I am a member of several of those subcommittees, and I feel that unless each member speaks as the mouthpiece of the organization he represents, instead of confining his remarks to an expression of his personal views, progress will be slow and any resulting standards will be in danger of being disregarded by the industry.

The essentials of successful standardization are, first, a full appreciation of the value and influence that standards can have on the development of an industry, and, secondly, the existence, or the creation, of the true community spirit to attain the ideal, or, failing that, the best workable average for any particular subject. The first of these essentials was given important recognition at a recent meeting of the International Chamber of Commerce held in London, where the members agreed to use their influence to propagate the idea and value of industrial standardization throughout the business world at large.

Standardization of Agricultural Tractors

Up to the present my remarks on the standardization of materials and parts have applied more particularly to such automobiles as passenger cars, motorcycles, omnibuses and various kinds of commercial vehicle, but there is another class of machine a consideration of which the automobile engineer should seriously take in hand without further delay. I refer to the agricultural

tractor. In the realm of agriculture, I believe, we are in very much the same position which in the automobile industry we held during the years 1904 to 1907; that is to say, we are just emerging from the experimental stage, and I am convinced that if this branch of the industry is handled intelligently it will prove to be one of the most useful and profitable ones. The application of motor power to farming has, up to the present, been admitted only on a very small scale, notwithstanding the fact that agriculture can truthfully be termed the basic industry. Viewed in that light, it does seem strange that it should have been carried on for so many years with such primitive implements. America has done more with regard to the use of machinery on farms than any other country, and the number of American-built tractors is very great.

Standardization can do much to advance this important branch of the industry, and I suggest that now is the time for those who are interested in the matter to arrive at an agreement for the standardization of such parts as cleats, clevises, spud attachments, belt speeds, height of drawbar, type of drawbar connection, method of control, carbureter flanges, air-filters, and a host of other matters. The necessity for standardization will be appreciated readily when I point out that the belt speeds on the tractors that participated in last year's trials at Lincoln varied from 1830 to 3760 ft. per min., and in the case of only three of them was the belt speed anywhere near correct with the engine running at its normal speed. As one of the principal things for which belt power is required on a farm is the driving of a threshing machine, it might be expected that the designers, in the first place, would have ascertained whether any standard had been arrived at among builders of such machines, and although so far as I am aware, there has never been any conference on the subject, I am informed by Sir William Tritton that all British steam traction-engines, portable engines, etc., are arranged to drive at a belt speed of 2200 ft. per min., and that this is equally true of German, Austrian, American and Canadian engines, with the result that any make of engine can run with any make of threshing machine. Moreover, all other types of machinery for use on farms and by contractors, such as saw benches, mortar mills and grinding mills, conform to these figures.

In the face of this agreement among builders of agricultural steam engines and machinery, it is difficult to understand how the newly developed internal-combustion tractor has come into being without any consideration being given by designers to this important point. This criticism applies to both British and foreign-built agricultural tractors. The difference among various makers is more pronounced in American-built tractors than in those of any other country.

International Standards

This brings us to a consideration of international standards, and in this connection it is interesting to note that Standards Committees are now at work in no fewer than 13 different countries, and that the British Engineering Standards Association is in close touch with them all. Recently an unofficial conference of all the secretaries of these organizations took place in London, which should do much to promote interchange between these bodies and assist in the important work. International Standardization is by no means a simple problem. There are immense difficulties in the way, and it can only go forward with the greatest caution and with adequate safeguards to British industry. Each country must protect its own trade requirements. It is well to recognize that our manufacturers may soon find that they are being asked to quote for foreign specifications, and for that reason every possible support should be given to the British Engineering Standards Association in its efforts to bring the specifications of all countries into harmony. Such a step can only be to the advantage of our export trade.

Standardization in Germany

In connection with international standardization, we ought to bear in mind that not more than three years ago a Standards Committee of the German industry was formed, and after less than 2 years' work it had published no fewer than 160 standard sheets and had over 400 more in progress. It is also interesting to note that the attitude of the German Standards Committee appears to be the standardization of manufacture rather than that of materials, the idea being the simplification of design so as to save both labor and material. Standards which they have already issued cover a very large field, including tools, gages, automobiles, agricultural machinery, locomotives, window frames, doors, stairs, roofing and a vast amount of other work that is undoubtedly assisting that country more than any other in the process of reconstruction. Technical development east of the Rhine needs to be most closely watched during the next 10 years. We should not forget that it was the cooperation of German engineers and capitalists during the 30 years following the Franco-Prussian War that raised Germany from an agricultural to a commercial nation; neither should we forget that the patience, genius and perseverance that created that change in the economic position of Germany is still alive.

STANDARDIZATION IN GERMANY

STANDARDIZATION has become a national craze in Germany in somewhat the same way as efficiency has in this country, according to the comments of engineers, scientists and manufacturers who have been to Europe since the war. The efficiency of German endeavor, in whatever line applied, is a matter of history, but the standardization idea did not develop into its full intensity until the war period. Now the fight for the world's trade is on, and Germany has cleverly recognized the fact that the country offering a wide choice of products, all of each kind being interchangeable, will have a marked advantage over its competitors on that account.

A national realization of the need for rebuilding its export trade, and of the part that standardization would play in securing it, has resulted in the formation of a national organization that is supported by the country's leading industrial and technical associations. It is analogous to our own American Engineering Standards Committee, but is apparently far more active, not only because of the present situation, but also, in all probability, because of the traditional German tendency toward submission to centralized authority.

England, too, is paying attention to the problem, though not with the same intensity that Germany is displaying. Perhaps some further effort along this line would be advisable in this country, in view of the increasing activity of America in international trade. Even for domestic reasons further standardization in many cases would be desirable and would go far toward the elimination of waste.—*Power.*

The 1921 Standards Committee

IN an issue of THE JOURNAL such as the present one is devoted largely to the results of standardization both in this country and abroad, it perhaps ss to call attention briefly to the personnel ponsible for the reports of the various Divie Standards Committee printed elsewhere in this number, and to give some facts concerning the work of the Committee for the year 1921. The Standards Committee as now organized consists of 27 Divisions, made up of approximately 350 members.

In the year now drawing to a close 42 Division meetings were held and in addition there were numerous informal meetings of different Subdivisions. The total cost to companies represented at these meetings was $16,000 or an average to each organization of $136. The estimated cost to the Society was $31,500 and, as the National Automobile Chamber of Commerce contributed $7500 to the work, the grand total cost is approximately $55,000. These figures necessarily cover work on subjects that will not be completed in the present year and also similar expenditures prior to last January for standards adopted this year, so that the figure given of $55,000 is probably a fairly accurate measure of cost of standardization by the Society in 1921. It does not include the time spent by Division members outside of the Division Meetings or that spent by Subdivision members outside of or at Division meetings. The average distance traveled to Division meetings per member is 1365 miles and the total number of miles traveled by all members attending the Division meetings is 191,100.

THE PERSONNEL

Photographs of the Chairman and Vice-Chairmen of the Standards Committee and of the chairmen of some of the Divisions are presented on the following pages. The personnel of the various divisions is given below.

STANDARDS COMMITTEE

B. B. Bachman, *Chairman*
W. R. Strickland, *Vice-Chairman*
W. A. Chryst, *Vice-Chairman*

AERONAUTIC DIVISION

H. M. Crane, *Chairman*	Consulting Engineer
V. E. Clark	General Motors Research Corporation
W. L. Gilmore	Curtiss Engineering Co.
L. M. Griffith	National Advisory Committee for Aeronautics
G. E. A. Hallett	Air Service
J. L. Harkness	L. W. F. Engineering Co.
J. C. Hunsaker	Bureau of Construction and Repair, Navy Department
F. M. Kraus	Bureau of Steam Engineering, Navy Department
L. B. Lent	Formerly of Air Mail Service
G. C. Loening	Loening Aeronautical Engineering Corporation
G. L. Martin	Glenn L. Martin Co.
G. J. Mead	Wright Aeronautical Corporation
W. H. Phipps	Ordnance Engineering Corporation
H. C. Richardson	Naval Aircraft Factory
W. T. Thomas	Thomas-Morse Aircraft Corporation
R. H. Upson	Gardner Moffat Co.
P. W. Wittemann	Wittemann-Lewis Aircraft Co., Inc.
E. C. Zoll	Post Office Department

AXLE AND WHEEL DIVISION

G. W. Dunham, *Chairman*	Savage Arms Corporation
C. C. Carlton, *Vice-Chairman*	Motor Wheel Corporation
T. V. Buckwalter	Timken Roller Bearing Co.
R. J. Burrows	Clark Equipment Co.
J. Coapman	Russel Motor Axle Co.
C. S. Dahlquist	Standard Parts Co.
F. W. Gurney	Gurney Ball Bearing Co.
G. L. Lavery	West Steel Casting Co.
A. M. Laycock	Sheldon Axle & Spring Co.
C. T. Myers	Consulting Engineer
A. L. Putnam	Detroit Pressed Steel Co.
J. G. Swain	Firestone Steel Products Co.
G. J. Thomas	Duplex Truck Co.

BALL AND ROLLER BEARINGS DIVISION

W. R. Strickland, *Chairman*	Peerless Motor Car Co.
F. W. Gurney, *Vice-Chairman*	Gurney Ball Bearing Co.
G. R. Bott	Norma Co. of America
H. E. Brunner	S.K.F. Industries, Inc.
E. R. Carter, Jr.	Fafnir Bearing Co.
D. F. Chambers	Bearings Co. of America.
L. W. Close	Bock Bearing Co.
F. G. Hughes	New Departure Mfg. Co.
G. L. Miller	Gilliam Mfg. Co.
H. J. Porter	Timken Roller Bearing Co.
R. G. Schaffner	Bower Roller Bearing Co.
R. E. Wells	Hyatt Roller Bearing Co.

CHAIN DIVISION

W. F. Cole, *Chairman*	Baldwin Chain & Mfg. Co.
W. J. Belcher	Whitney Mfg. Co.
A. E. Brion	Peter A. Frasse & Co., Inc.
H. F. L. Funke	Herbert F. L. Funke Co., Inc.
J. C. Howe	American High Speed Chain Co.
F. L. Morse	Morse Chain Co.
H. S. Pierce	Link-Belt Co.
L. M. Wainwright	Diamond Chain & Mfg. Co.

ELECTRIC VEHICLE DIVISION

E. L. Clark, *Chairman*	Commercial Truck Co.
Karl Probst, *Vice-Chairman*	Milburn Wagon Co.
G. L. Bixby	Detroit Electric Car Co.
J. G. Carroll	Walker Vehicle Co.
F. E. Queeney	Lansden Co., Inc.
C. A. Ward	Ward Motor Vehicle Co.

ELECTRICAL EQUIPMENT DIVISION

A.D. T. Libby, *Chairman*	Splitdorf Electrical Co.
F. W. Andrew, *Vice-Chairman*	Eisemann Magneto Corporation
Azel Ames	Kerite Insulated Wire & Cable Co.
W. A. Chryst	Dayton Engineering Laboratories Co.
S. F. Evelyn	Continental Motors Corporation
C. F. Gilchrist	Electric Auto-Lite Corporation
W. S. Haggott	Packard Electric Co.
T. L. Lee	North East Electric Co.
B. M. Leece	Leece-Neville Co.
Charles Marcus	Bijur Motor Appliance Co.
R. G. Thompson	Westinghouse Electric & Mfg. Co.
A. H. Timmerman	Wagner Electric Mfg. Co.
C. E. Wilson	Remy Electric Co.
Ernest Wooler	Cleveland Automobile Co.

W. A. CHRYST

W. R. STRICKLAND

B. B. BACHMAN

H. M. CRANE

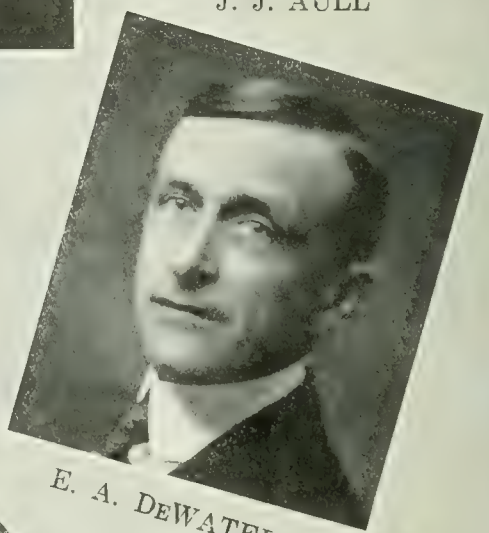
F. P. GILLIGAN

RALPH MURPHY

T. C. MENGES

J. J. AULL

BRUCE FORD



E. A. DEWATERS

JOSEPH VANBLERCK

L. S. KEILHOLTZ

W. S. HARLEY

C. E. GODLEY

E. A. JOHNSTON

G. W. DUNHAM

A. D. T. LIBBY

E. H. EHRMAN

A. W. COPLAND

J. B. FISHER

A. K. BRUMBAUGH

ENGINE DIVISION

J. B. Fisher, *Chairman*	Waukesha Motor Co.
R. J. Broege, *Vice-Chairman*	Buda Co.
P. J. Dasey	Midwest Engine Co.
[illegible] Evelyn	Continental Motors Corporation
[illegible]ath	Wisconsin Motor Mfg. Co.
[illegible]nt	Research Engineer
[illegible]itzer	Automotive Parts Co.
[illegible]nan	Herschell-Spillman Motor Co.
[illegible]e	Packard Motor Car Co.

FRAMES DIVISION

E. A. DeWaters, *Chairman*	Buick Motor Co.
L. J. Fralick, *Vice-Chairman*	Hydraulic Pressed Steel Co.
C. C. Bowman	Standard Motor Truck Co.
O. B. Harman	Parish & Bingham Co.
E. L. Larson	The Locomobile Co.
W. A. McKinley	Detroit Pressed Steel Co.
F. R. Pleasonton	Parish Mfg. Co.

IRON AND STEEL DIVISION

F. P. Gilligan, *Chairman*	Henry Souther Engineering Corporation
W. C. Peterson, *Vice-Chairman*	Atlas Crucible Steel Co.
R. M. Bird	Bethlehem Steel Co.
A. L. Colby	Consulting Metallurgist
C. N. Dawe	Studebaker Corporation of America
B. H. DeLong	Carpenter Steel Co.
A. P. Eves	International Harvester Co.
E. L. French	Crucible Steel Co. of America
W. F. Graham	Henry Souther Engineering Corporation
H. L. Greene	Willys-Overland Co.
C. G. Heilman	General Motors Corporation
J. B. Johnson	Air Service
F. C. Langenberg	Ordnance Department
C. S. Moody	Minneapolis Steel & Machinery Co.
J. H. Nelson	Wyman-Gordon Co.
G. L. Norris	Vanadium Corporation of America
M. P. Rumney	Detroit Steel Products Co.
C. F. W. Rys	Carnegie Steel Co.
H. J. Stagg	Halcomb Steel Co.
J. M. Watson	Hupp Motor Car Corporation

ISOLATED ELECTRIC LIGHTING PLANT DIVISION

L. S. Keilholtz, *Chairman*	Delco-Light Co.
G. E. Tubbs, *Vice-Chairman*	Alamo Farm Light Co.
F. C. Barton	General Electric Co.
L. F. Burger	International Harvester Co.
T. P. Chase	Lalley Light Corporation
A. S. Denes	S. W. Merritt Co.
G. M. Gardner	Globe Electric Co.
L. W. Heath	Litscher Lite Corporation
S. J. Matthews	Matthews Co.
E. B. Newill	Westinghouse Electric & Mfg. Co.
C. E. Reddig	Western Electric Co.
Samuel Wilbur	Auto-Lite Corporation

LIGHTING DIVISION

C. E. Godley, *Chairman*	Edmunds & Jones Corporation
W. A. McKay, *Vice-Chairman*	H. W. McCandless & Co.
P. F. Bauder	National Lamp Works
F. M. Holden	Cadillac Motor Car Co.
C. A. Michel	Guide Motor Lamp Mfg. Co.
Henry Platz	Gray & Davis Lamp Division of Alvo Mfg. Co.
E. S. Preston	Chicago Electric Mfg. Co.
C. D. Ryder	Corcoran-Victor Co.
C. H. Sharp	Electrical Testing Laboratories
J. C. Stearns	Culver-Stearns Mfg. Co.

LUBRICANTS DIVISION

H. C. Mougey, *Chairman*	General Motors Research Corporation
W. E. Jominy, *Vice-Chairman*	Studebaker Corporation of America
A. P. Eves	International Harvester Co.
W. H. Herschel	Bureau of Standards
W. E. Perdew	Union Petroleum Co.
H. G. Smith	Atlantic Refining Co.

MOTORBOAT DIVISION

Joseph VanBlerck, *Chairman*	Wellman-Seaver-Morgan Co.
H. H. Brautigam, *Vice-Chairman*	Bridgeport Motor Co.
Irwin Chase	Elco Works
G. F. Crouch	Webbs' Academy and Home for Shipbuilders
G. C. Davison	New London Ship & Engine Co.
W. J. Deed	United States Mail Steamship Co., Inc.
H. E. Fromme	Consolidated Shipbuilding Corporation
W. C. Morehead	Great Lakes Boat Bldg. Corporation

MOTORCYCLE DIVISION

W. S. Harley, *Chairman*	Harley-Davidson Motor Co.
C. B. Franklin, *Vice-Chairman*	Hendee Mfg. Co.
A. J. Hall	Cleveland Motorcycle Mfg. Co.
F. W. Schwinn	Excelsior Motor Mfg. & Supply Co.

NON-FERROUS METALS DIVISION

J. J. Aull, *Chairman*	Lunkenheimer Co.
E. Blough, *Vice-Chairman*	Aluminum Co. of America
W. H. Bassett	American Brass Co.
A. G. Carman	Franklin Die-Casting Corporation
D. L. Colwell	Stewart Mfg. Co.
G. K. Elliott	Lunkenheimer Co.
E. S. Fretz	Light Mfg. & Foundry Co.
Zay Jeffries	Aluminum Manufactures, Inc.
A. W. Kinman	Precision Castings Co.
H. C. Mougey	General Motors Research Corporation
Charles Pack	Doehler Die-Casting Co.
H. P. Parrock	Lumen Bearing Co.
W. C. Peterson	Atlas Crucible Steel Co.
W. B. Price	Scovill Mfg. Co.
L. D. Simpkins	National Lead Co.
Samuel Tour	Doehler Die-Casting Co.
W. R. Webster	Bridgeport Brass Co.
E. S. Wheeler	International Nickel Co.
R. W. Woodward	Bureau of Standards

PARTS AND FITTINGS DIVISION

Clarence Carson, *Chairman*	Dodge Bros.
F. G. Whittington, *Vice-Chairman*	Stewart-Warner Speedometer Co.
J. R. Coleman	Selden Motor Truck Corporation
H. S. Jandus	C. G. Spring Co.
W. C. Keys	Eaton Axle Co.
F. W. Slack	Peerless Motor Car Co.
C. W. Spicer	Spicer Mfg. Corporation

PASSENGER CAR DIVISION

Ralph Murphy, *Chairman*	H. H. Franklin Mfg. Co.
R. S. Begg, *Vice-Chairman*	Jordan Motor Car Co.

L. A. Chaminade	Studebaker Corporation of America
H. Clark	Westcott Motor Car Co.
A. M. Dean	Templar Motors Corporation
A. W. Frehse	Standard Steel Car Co.

PASSENGER-CAR BODY DIVISION

E. G. Budd, *Chairman*	Edward G. Budd Mfg. Co.
G. E. Goddard, *Vice-Chairman*	Dodge Bros.
J. S. Burdick	Buffalo Body Corporation
F. C. Chapman	Brewster & Co.
O. H. Clark	Willys Corporation
A. E. Garrels	Studebaker Corporation of America
G. W. Kerr	Racine, Wis.
G. J. Mercer	Consulting Engineer
A. J. Neerken	Hupp Motor Car Corporation
H. C. Nelson	Mullins Body Corporation
Victor Preston	Haynes Ionia Co.
E. G. Simpson	Fisher Body Corporation

RADIATOR DIVISION

J. D. Harris, *Chairman*	McCord Mfg. Co., Inc.
C. S. Sage, *Vice-Chairman*	Sage Radiator Co., Inc.
D. L. Britton	Templar Motors Corporation
H. B. Knap	Packard Motor Car Co.
Charles Oppe	G & O Mfg. Co.
C. T. Perkins	Modine Mfg. Co.
G. H. Pettit	Atterbury Motor Car Co.
G. W. Smith	Nash Motors Co.
K. F. Walker	Fedders Mfg. Co.
E. E. Wemp	Long Mfg. Co.
J. A. White	Harrison Radiator Co.
J. G. Zummach	Perfex Radiator Co.

SCREW THREADS DIVISION

E. H. Ehrman, *Chairman*	Chicago Screw Co.
O. B. Zimmerman, *Vice-Chmn.*	International Harvester Co.
Earle Buckingham	Pratt & Whitney Co.
E. Burdsall	Russell, Burdsall & Ward Nut & Bolt Co.
Luther Burlingame	Brown & Sharpe Mfg. Co.
W. R. Mitchell	National Acme Mfg. Co.

SPRINGS DIVISION

R. A. Schaaf, *Chairman*	Sheldon Axle & Spring Co.
S. P. Hess, *Vice-Chairman*	Detroit Steel Products Co.
H. R. McMahon	Standard Steel Spring Co.
W. M. Newkirk	William & Harvey Rowland, Inc.
Gustof Peterson	Electric Alloy Steel Co.
F. A. Whitten	General Motors Truck Co.

STATIONARY ENGINE DIVISION

T. C. Menges, *Chairman*	Associated Manufacturers Co.
L. F. Burger, *Vice-Chairman*	International Harvester Co.
H. N. Edens	John Lauson Mfg. Co.
W. W. Gore	Fuller & Johnson Co.
H. G. Holmes	Novo Engine Co.
V. E. McMullen	Hercules Gas Engine Co.
I. J. Nelson	Nelson Bros.
L. M. Ward	Cushman Motor Works

STORAGE BATTERY DIVISION

Bruce Ford, *Chairman*	Electric Storage Battery Co.
W. E. Holland, *Vice-Chairman*	Philadelphia Storage Battery Co.
W. H. Bancroft	Edison Storage Battery Co.
G. L. Bixby	Detroit Electric Car Co.
R. N. Chamberlain	Gould Storage Battery Co.
E. L. Clark	Commercial Truck Co.
R. J. Ellis	Seneca Battery Corporation
C. T. Klug	Willard Storage Battery Co.
I. M. Noble	Prest-O-Lite Co., Inc.
A. R. Reid	U. S. Light & Heat Corporation

TIRE AND RIM DIVISION

J. G. Vincent, *Chairman*	Packard Motor Car Co.
A. L. Viles	Rubber Association of America
H. M. Crane	Consulting Engineer
H. H. Rice	Cadillac Motor Car Co.

TRACTOR DIVISION

E. A. Johnston, *Chairman*	International Harvester Co.
John Mainland, *Vice-Chairman*	Advance-Rumely Co.
J. H. Davis	General Motors Research Corporation
A. H. Gilbert	Rock Island Plow Co.
R. O. Hendrickson	J. I. Case Plow Works Co.
M. B. Morgan	Cleveland Tractor Co.
C. B. Rose	Moline Engine Co.
A. W. Scarratt	Minneapolis Steel & Machinery Co.
O. W. Sjogren	University of Nebraska
L. W. Witry	Waterloo Gasoline Engine Co.
G. A. Young	Purdue University

TRANSMISSION DIVISION

A. W. Copland, *Chairman*	Detroit Gear & Machine Co.
A. C. Bryan, *Vice-Chairman*	Durston Gear Corporation
A. M. Dean	Templar Motors Corporation
J. B. Foote	Foote Bros. Gear & Machine Co.
L. C. Fuller	Fuller & Sons Mfg. Co.
A. A. Gloetzner	Covert Gear Co., Inc.
C. O. Guernsey	Service Motor Truck Co.
A. W. S. Herrington	Quartemaster Corps
W. C. Lipe	Brown-Lipe Gear Co.
C. E. Swenson	Mechanics Machine Co.
S. O. White	Warner Gear Co.

TRUCK DIVISION

A. K. Brumbaugh, *Chairman*	Autocar Co.
F. A. Whitten, *Vice-Chairman*	General Motors Truck Co.
W. M. Britton	Britton Axle Co.
G. S. Cawthorne	Master Trucks, Inc.
J. R. Coleman	Selden Truck Corporation
F. W. Davis	Pierce-Arrow Motor Car Co.
H. E. Derr	International Harvester Co.
C. O. Guernsey	Service Motor Truck Co.
M. C. Horine	International Motor Co.
H. B. Knap	Packard Motor Car Co.
A. J. Scaife	White Motor Co.

STANDARDIZATION AND INVENTION

THE inventor of the future will undoubtedly have a harder road to travel to success than his predecessor. Standardization, a big factor in industrial economy, will prevent the easy adoption of something new unless it be a very substantial improvement. This is one of the advantages of standardization. Standardization may be a stumbling block to inventors, but real inventors are then at their best.

Standardization may make a path a little steeper and harder for the man with a good idea, but if the idea and the man are really worthwhile, they will triumph. No artificial barriers can be permanently erected against real improvements, and the standardization that makes it harder for the inventor to obtain recognition will in turn serve to spur him on to achieve greater perfection. Standardization will never stop an Edison, Howe, Whitney, Morse or Bell.—Spencer Miller in *Industry Illustrated.*

Strength Through Standardization[1]

By G. Brewer Griffin[2]

STANDARDIZATION of a product, so far as is possible, directly benefits both the manufacturer and the user, as well as the producer of the raw materials that enter into it. The matter of standardization is a sore spot with many engineers. The oldtime engineer felt that unless he could design something that did not exist in the Heavens above, the earth beneath or the waters under the earth, he was not performing in a way that would warrant his title of engineer. Possibly this attitude is all right so long as the product manufactured is sold and serviced solely by the individual or the organization producing it. But just as soon as distribution of such a product becomes general, and the service requirements are national or international, the nearer we approach to accepted standards the better it is for everyone concerned.

Whether the manufacturer is entitled to furnish all service parts of his original manufacture depends upon two things: first, control by patents that would shut out the furnishment by anyone else; and, second, and most important, the worthiness of the manufacturer to receive this business and obtain it by the scope and quality of his service and the relations he maintains with his buyers and users.

Work of Standards Committee

One great good that has benefited the industry is the work of the Standards Committee of the Society of Automotive Engineers. While it has been said that "Standards Committee members spend months agreeing upon some standard, and then hurry back to their own plant and adopt something different," this is not always the truth. It must be admitted that standards have placed the American motor car in the preeminent position it occupies in the world, because the standardization of materials and parts has enabled the steel mills, the nut and bolt manufacturers and hundreds of other similar suppliers to manufacture and place in stock certain of their materials and parts that have been ordered by Tom, but may sooner or later be purchased by Dick or Harry. This has reduced production cost, and the benefits have been given to this industry and in turn passed along to the car owner more than the absence of such standards could ever have done.

Another advantage, to borrow one of ex-President Wilson's expressions, is "the meeting of minds" in association work, particularly where the problems discussed are those that confront everyone present. Out of such informal discussion comes the consideration of standards, whether these standards be employment methods, purchasing methods, methods of operation, cost accounting systems, credit interchange, exchange of experience on materials and treatments, supply sources or contract methods.

Individual Frankness a Benefit to the Industry

Any man who attends a meeting of a group of his fellow manufacturers, keeping in mind that he himself has no particular corner on brains, or any other commodity entering into his business and that he has access to no methods that his competitors cannot just as well have, will learn much and rapidly advance his industry by a frank and outspoken policy in regard to the various phases of his business. This in turn invites like confidences from his associates, and a study of the problem often brings about improved manufacturing methods and better products with it.

In the accessory industry there is, as there has been in years past, a great need of group association, which has heretofore only partially been supplied by the Motor & Accessory Manufacturers Association. Its membership, representing almost every class of industry that deals with automotive vehicle manufacture, aircraft, motorboats and the like, could not in open meetings discuss any particular phase of a problem with a certainty that it would be interesting or helpful to every member present. The result was that individual groups soon associated themselves together outside of the parent Association until it became a case of wheels within wheels without any fixed plan for the heading up of all the branches of the industry and consequently stabilizing the whole.

The Association has taken the one great step forward in offering the opportunity and facilities for its members to operate with and through the parent body, which is the only means by which the various interests are to be harmonized and individual interest broadened. This movement among us is still new, but the interest that has been displayed in it and the groups already formed show that there has been for a long time a need for this action.

Methods Influence Success

The future success and profits of the business in which we are interested is dependent upon the methods we adopt to handle it, and the policies we inaugurate to deal with it. We all have individual opinions; let us make them Association opinions, and in this unity of views and purposes will doubtless lie our future strength and assured success.

I look forward with confidence to the time when we shall work closer and closer with the National Automobile Chamber of Commerce and the Society of Automotive Engineers; our interests are all mutual. It is not unreasonable to suppose that the time may come, after our group plan is perfected and completed, when these present three named bodies will be in fact the three great groups of the one great universal association of the automotive industry.

In individuality there is sometimes strength; in unity there is always strength. I think this is a good slogan for us to use.

[1] From an address before the credit convention of the Motor & Accessory Manufacturers Association.

[2] M S A E Manager [illegible] equipment department, Westinghouse Electric & Mfg. Co., Springfield, Mass.

DEVELOPMENTS IN PISTON DESIGN

THROUGH a regrettable oversight credit for the material used in preparing the article Developments in Piston Design that appeared on page 199 of the September issue of The Journal was not given to the English magazine *Autocar*. This article was based upon the information contained in the English periodical and the illustration was taken from the same source.

S. A. E. Standardization

By George W. Dunham[1]

CITING examples that show the existence of the idea of standardization in the mind of man almost since the dawn of history and stating that this idea has been a prime factor in the advancement of the world at large, the author acknowledges that standardization does not materialize easily and that it is not always correct in its inception, but believes it an essential to modernism and that it can be developed successfully in an industry composed of independent and competing manufacturers through the necessities and desires of the majority.

This belief is amplified in the subsequent thought and comprises discussion relating to the origin of automotive standardization, non-segregation of engineers, accomplishments, standardization procedure, the wide cooperation with the Society that is now effective and the opinions regarding standardization expressed by representative firms. The author concludes that the standards work should be promulgated as vigorously as in the past and that it should receive even greater and more aggressive support.

STANDARDIZATION may be defined as the adoption of a particular method or means by which to accomplish a desired result; its scope as with most things is relative. It may be limited as to usefulness, but whether it be the accepted method of accomplishment by an individual or many, if it is accepted for usual practice it becomes standard whether dignified by that name or not.

When a mathematician develops a formula, or a manufacturer a special operation or a definite dimension for a certain purpose and adopts it as his way of doing that particular thing it becomes standard with him. If others adopt it, its scope of usefulness increases and if it be of particular merit it becomes a valuable adjunct to the art to which it applies in proportion to its acceptance.

It is felt by some that standardization is something new and perhaps a fad, but it has been with man almost since the beginning and has been a prime factor in the advancement of the world at large. Only through standardization is it possible to obtain the many things requisite to everyday life without having to describe one's wants definitely, and then to institute a search to find that which supplies them. It is today difficult to imagine an existence without an accepted standard of measurement, whether it be that of distance, volume, time, or what not; yet at one time these now simple things placed at our disposal were non-existent, and it is amusing to try to visualize the trials and tribulations of those who first attempted to convince the public of their usefulness. Obtaining wearing apparel by sizes and food in packages in which are given quantities and material of definite quality are conveniences accepted as a matter of fact and of minor detail, but in reality they are of importance as affecting our economic life and are examples of standardization which lie so close to us that we do not realize the work and effort that were necessary to place them at our disposal.

Standardization Inevitable in Modernism

Standardization does not come easily, nor is it always correct in its inception. It is an essential to modernism, especially manufacturing life, and will develop whether a definitely organized effort is put forth or it is allowed to drift aimlessly. Obviously, the former will accelerate the results and the advantages derived from it.

Many commonplace things, good examples of which are the yard and the calendar, were not satisfactory the first time they were attempted, and after many years there is still much discussion as to what should be the universal standard of measurement of distance; yet we would not, in fact could not, possibly discontinue either the millimeter or the inch except through a long period of transition, although it is questionable if one or the other is not inferior.

In an industry composed of independent and competing manufacturers, successful standardization can be developed only through necessity or the desires of a large majority. It is impossible for a small or minor group to force a standard of their creation on any individual or group of individuals, but where the necessity of such a thing exists or a large number of those interested desire it, the practice will become standard whether it is formally developed through concerted action or not. If it is allowed to come about unaided, much time will be required and many unnecessary difficulties experienced before the ultimate is reached, but when a proposition is given study by a highly organized body of interested people, the needs of all investigated, and everyone given an opportunity to voice his opinion and act on the final result, it is difficult to imagine other than a satisfactory and desirable standard except perhaps in rare cases where the necessity or desire does not exist. By such effort properly coordinated there need be but a minimum lapse of time before those interested can realize on the many benefits to be derived. Furthermore, regardless of the number adopting a standard, any individual is naturally free to proceed as he may feel is best for his particular needs, without being any worse off than he would have been had the others not decided to do that particular thing in the same particular way.

In the past there have been isolated cases of manufacturers with a replacement business of such a magnitude that they have deliberately made their products non-interchangeable with those of similar makes even in minor detail to try to insure their control of the sale of spare parts, but almost invariably they have found themselves isolated from the standpoint of possible cooperation and usually been unable to meet price competition on account of their greater cost of manufacture.

Origin of Automotive Standardization

In the early days of the automotive industry the need of a closer contact of the various organizations, especially the engineers, was keenly felt as a means of more rapidly and economically advancing the art. This resulted in what was known as the Mechanical Branch of the Association of Licensed Automobile Manufacturers, made up of the engineering talent of the many companies forming that association. One of the first duties consisted of studying the possibilities of standardization. With an entirely new field in which to work and much enthusiasm almost immediate results were forthcoming, although not always satisfactorily as much had to be learned as to the proper method of procedure. It was found that what

[1] M. S. A. E.—Consulting engineer, Savage Arms Corporation, New York City.

looked very simple was most intricate and difficult of accomplishment. About the same time the Society of Automobile Engineers was formed, embracing all the different activities having to do with the internal-combustion engine. In 1910, after the discontinuance of the Associa- Licensed Automobile Manufacturers' Mechanical began a study of standardization and, like the Branch, found the apparently easy path h pitfalls, which it took years of study and effort to learn how to overcome. All of the he Mechanical Branch were turned over to the Society, thus combining the resources of both organizations and advancing the work at one step as could not otherwise have been done during a period of years. This is now ancient history, but has a direct bearing on the situation today as being indicative of the immense amount of thought, "know how" and effort that lies back of the present-day standards work of the Soceity. The amalgamation in 1917 of the Society of Automobile Engineers with the other proponents of the internal-combustion engine, forming the present Society of Automotive Engineers, made still greater results possible in that it brought together with a common aim all those groups of engineers formerly working separately, encouraging more frequent association between them and the executives, production men and salesmen, without whose proper cooperation the best results are obviously impossible.

Non-Segregation of Engineers

It is thought by some that the Society of Automotive Engineers should be composed only of engineers in the strictest sense of the word, and at its gatherings only strictly technical papers should be presented. Unlike most engineering organizations, there is in the Society a great bond of common interest in the advancement of a specific industry, young as yet, the very back-bone of which is standardization. The greatest good is to be accomplished by the direct support of all departments and the consideration of all phases of the problem rather than with a limited and unsupported group as would be the case if the engineers segregated themselves and discussed only technical problems.

Things Accomplished

Standardization as pertaining to the Society of Automotive Engineers obviously has to do with things automotive, and while much has been accomplished without which the monetary values of the various automotive products today would be impossible, there is yet a greater work to be done. Those of the Society who have been active in standardization work to date and those who have given their support can hardly feel other than gratified at the satisfactory progress that has been made. To these men the world at large owes an immense debt, suitable appreciation of which would be difficult to express. Automotive standardization has accomplished much. At one time there were 135 different analyses of steel being used; today this requirement has been reduced to 47. There were originally 88 different sizes of lens, while at present 4 sizes are all that are necessary. The maker of crankshaft grinding-wheels need furnish today but 15 sizes, as against 29 of yesterday, while the number of radii for these wheels has been reduced from 7 to 1. The number of sizes of flexible metal-tubing as required has been reduced from 52 to 28, radiator-cap sizes from 58 to 15, tank-cap sizes from 60 to 15, to say nothing of the excellent and most valuable work on bell-housings, magneto bases, steel tubing, bearing sizes, screw threads, non-ferrous metals and steel and other specifications too numerous to mention. When one considers the enormous saving in tools, simplification of manufacture from the standpoint of handling, increased volume of like pieces, reduction of inventory necessary for production and service, and the ability to obtain material and equipment promptly, one must say a "Big Work Well Done."

The following are some of the many established standards, the years in which they were adopted being specified:

Annular Ball-Bearings	1911
Carbureter Flanges	1912
Electric Incandescent Lamps	1918
Engine Testing Forms	1917
Flywheel Housings	1915
Generator Mountings	1917–1918
Headlamp Illumination	1918
Insulated Wire and Cable	1916
Steels	1912
Lamp Glasses	1919
Lead-Acid Storage-Batteries	1914
Magneto Mountings	1913
Motor-Truck Springs	1915
Non-Ferrous Metals	1911
Passenger-Car Springs	1915
Pneumatic Tires	1915
Rod-Ends and Pins	1911
Roller Chains	1918
Screws, Bolts and Nuts	1911
Seamless Steel Tubing	1911
Silent Chains	1917
Solid Tires	1919
Spark-Plug Shells	1915
Splines	1914
Starting-Motor Mountings	1917–1919
Thrust Ball-Bearings	1917

Procedure

A subject for standardization may be proposed from any competent source. Upon determining the suitability of the proposed subject, it is assigned to a Division or Subdivision of the Standards Committee and data collected. A tentative recommendation is then prepared by the Division or Subdivision and circularized in the trade for comments. If extensive revisions are necessary, the recommendation is again generally circularized and a final recommendation reported to the Standards Committee, which meets regularly twice a year. Upon approval of the report by the Standards Committee, it is balloted upon by the entire voting membership of the Society before publication in the S.A.E. Handbook. Standards may be revised from time to time or may be cancelled.

The different classes of standards are

(1) Those including such specifications as have become more or less permanent through sound or well-established engineering use
(2) Recommended practices including subjects that at the time of adoption are not so well established but for which a definite practice is desired
(3) A class of subjects, published as General Information, usually closely related to the S. A. E. Standards or Recommended Practices, but which are not official recommendations of the Society

The Standards Committee has grown from a relatively small group of perhaps a score to a body in 1921 consisting of 356 members grouped into 27 Divisions. There are two general classes of Divisions, one representing each main automotive group, such as the Aeronautic, the Passenger Car, the Motor Truck and the Motorboat Divisions, and the other representing classified materials and parts such as the Non-Ferrous Metals, the Iron and Steel,

the Parts and Fittings, the Ball and Roller Bearing, the Engine and the Electrical Equipment Divisions. Divisions are further divided into permanent or temporary Subdivisions as occasion may require, each to consider a particular subject assigned to it.

Wide Cooperation

The Society of Automotive Engineers cooperates directly or indirectly with

American Bureau of Welding
American Engineering Standards Committee
American Gear Manufacturers Association
American Institute of Electrical Engineers
American Malleable Castings Association
American Petroleum Institute
American Society for Steel Treating
American Society for Testing Materials
American Society of Agricultural Engineers
American Society of Mechanical Engineers
Automotive Electric Association
Automotive Metal Wheel Association
Chamber of Commerce of the United States of America
Electric Power Club
Gas Engine & Farm Power Association
Grinding Wheel Manufacturers Association
Illuminating Engineering Society
International Acetylene Association
Lamp Standardization Exchange
Manufacturers Aircraft Association
Motor & Accessory Manufacturers Association
Motor Truck Association of America
National Association of Engine & Boat Manufacturers
National Automobile Chamber of Commerce
National Conference on Highway Traffic Regulation
National Electric Light Association
National Implement & Vehicle Association
National Research Council
National Safety Council
Rubber Association of America
Tire & Rim Association
Trailer Manufacturers Association of America
Underwriters Laboratories
Wood Wheel Manufacturers Association

It also cooperates with the following Government departments and organizations:

Department of Commerce, Bureau of Standards
Department of Labor
National Advisory Committee for Aeronautics
National Screw Thread Commission
Navy Department
Post-Office Department
United States Coast Guard
United States Forestry Service
United States Weather Bureau
War Department, Ordnance Department

The Handbook

The Society is, it is believed, the only organization of the kind that has undertaken and carried into effect a loose-leaf form of engineers' reference book. This is of pocket size and known as the S.A.E. Handbook. The sheets, the preparation of which involves a large amount of detail, are furnished to the members without cost in addition to the conventional dues, supplemental and revised sheets being distributed twice a year together with uptodate indices when required.

The Personal Equation

What the development of the next decade or of the next generation will be, none probably can conceive, but it is clear that the essential necessity of cooperative work will be more and more appreciated. No one can reach his attainable development intellectually or professionally without sharpening his wits through much contact with men in and out of his own station of life. It is often said that those who give shall receive, and it is indicated strongly that those who do not give to others in some material degree the benefit of their practical and scientific experience, never receive as much as they could and should, and they can never be assured of being right in deductions as to data that they endeavor tenaciously to develop and hold exclusively.

Opinions Expressed

Replies to inquiries sent recently to prominent executives and engineers in the automotive industries have shown that the monetary saving effected by the use of S.A.E. standards is inestimable. The following statements have been made in regard to their value.

Peerless Motor Car Co.

We believe standardization to be of great help to the industry, provided the standards are kept uptodate. We intend to continue using them in our products where applicable.

W. R. Strickland, Chief Engineer.

Packard Motor Car Co.

It is perfectly obvious that S. A. E. Standards have greatly lowered the cost of production and that on account of these lower costs manufacturers are able to market their cars at a lower figure. It is my belief that S. A. E. Standards will become more valuable from year to year.

J. G. Vincent, Vice-President.

Cleveland Automobile Co.

S. A. E. Standards are very valuable, especially from a purchasing standpoint, and are of great assistance in design and inspection. They permit absolute interchangeability, which would otherwise be impossible.

Ernest Wooler, Chief Engineer.

International Harvester Co.

The results of S. A. E. Standards, which have been given careful and full attention by competent committees covering all engineering commercial angles, are distinctly valuable. They establish a uniform practice in industry, guarantee confidence in the conclusions reached, and elevate the average output of industry.

We are completely converted to the using of standardized designs, materials, methods and data, as we know these do not necessarily interfere with creative engineering and tend to raise the standards of the machinery produced, as well as reduce costs of production. We can produce a better article at the same cost than we could without standards such as the S. A. E. is developing.

O. B. Zimmerman, Research Engineer.

Minneapolis Steel & Machinery Co.

S. A. E. Standards are of utmost importance from the engineering, production and purchasing standpoints. They are conspicuous among the greatest achievements and most valuable assets of the Society and the automotive industry.

A. W. Scarratt, Engineer.

Splitdorf Electrical Co.

S. A. E. Standards have been of great value to the industry. There is still much to be done.

A. D. T. Libby, Chief Engineer.

Brown-Lipe Gear Co.

We believe that S. A. E. Standards are of marked value and that they effect large savings. We will continue to use them wherever possible.

A. E. Parsons, General Manager.

Timken Roller Bearing Co.

The use of standards has the effect of reducing the cost of manufacture and therefore reducing the cost of

automotive equipment. We feel that the greatest benefit has resulted in the standardization of tire sizes, bolts, nuts, lock washers and in general those fittings that are used by practically all manufacturers and do not in any way detract from the individual car by their [illegible]tion and use.

T. V. BUCKWALTER, Chief Engineer.

[illegible]dard Steel Spring Co.

Standardization is by far the most valuable work of [illegible]ociety. I really do not know how to express this in [illegible]'s and cents or in percentage, but I do know the [illegible]ng due to the adoption of standards is enormous.

H. R. MCMAHON, President.

Russell Motor Axle Co.

We believe that the adoption of S. A. E. Standards reduces manufacturing costs, makes possible sources of supply for small parts at lower prices, and adds to the prestige of any concern adopting them.

J. COAPMAN, Chief Engineer.

Timken Detroit Axle Co.

It would be quite impossible to put down in definite figures all the financial advantage accruing from the S. A. E. Standards. It no doubt has been very considerable and has of course affected our product although not to such a great extent possibly as in the case of the automobile manufacturers.

The S. A. E. HANDBOOK is probably the most used handbook among automobile designers. The writer is continually turning to it for information, and prefers it to any other handbook we have for general work.

H. W. ALDEN, President.

CONCLUSION

It is hoped that this article will serve to stimulate thought which will result in further appreciation of the value of S.A.E. Standards as they exist at present, and of the necessity and wonderful possibilities of their future development.

If the combined judgment of practically all the automotive engineers of this Country can be considered a criterion, and surely the remarkable results accomplished prove their ability, one must indeed be courageous to criticize adversely their unanimous support and adoption of S.A.E. Standards.

There is still much to be done that will result in great advancement of the industry and the art. It is most desirable that the Standards work be pushed forward as vigorously as in the past, and that it shall receive even greater and more aggressive support, to the end that the American car and other automotive products shall continue to hold their present enviable position.

DIRECTION-FINDING WIRELESS

THE principal use of direction-finding wireless as an aid to navigation is in enabling the bearing of a vessel in open waters, or when approaching pilotage waters, to be determined from one or more fixed points. When the bearings from two or more fixed points are obtained simultaneously the position of the vessel can be located by the intersection of the bearings. Independent of technical systems, there are three types of direction-finding wireless that may be employed as an aid to the navigation of ships. These are

(1) The direction-finding station type
(2) The beacon station type
(3) The directional transmitting station type

In the first type a vessel transmits signals by her ordinary wireless installation to a fixed station, or stations, on shore that are fitted with directional wireless apparatus. The shore station determines the bearing and transmits it to a ship in the ordinary manner. Two or more stations can be grouped to determine the bearing of the vessel from each station simultaneously, and the intersection of the respective bearings, as transmitted by ordinary wireless telegraphy to the vessel by the master station of the shore group, enables the position of the vessel to be ascertained. In this case the responsibility for the accuracy rests with the station and the vessel herself requires no special direction-finding apparatus.

In the beacon station type the vessel is fitted with direction-finding apparatus by which the relative bearing of one or more ordinary fixed transmitting stations can be determined and the vessel's position located by the intersection of the bearings. These are necessarily obtained relatively to the ship's course at the time and are corrected accordingly. Any known ordinary wireless telegraph station can be used for this purpose, or, preferably, certain stations known as beacon stations may be directed to transmit simultaneously, or successively, prearranged signals on certain wave-lengths at definite times during each hour. Under this system the responsibility for the accuracy of the bearing rests with the vessel, which must have a special direction-finding apparatus on board.

In the third method a rotating directional wireless beam having a fixed angular velocity is transmitted by a specially equipped fixed transmitting station. The rotating beam, which swings round in similar fashion to the revolving beam of a lighthouse, has a sharply-defined zero position which passes through north and south at given times. Knowing the angular velocity of the beam, and by observing the time-interval between the given times at which the zero passes through north and south and the time at which the zero signals are received in the ship, the bearing of the station can be determined. To insure that the watches in the transmitting station and the receiving ships are synchronized the station transmits a timing signal before commencing the rotating beam. To avoid calculation in the ship, and to obtain greater accuracy, a special watch, the face of which is marked in degrees, is required on the ship, and the scale corresponding to the angular velocity of the revolving beam. If this watch is started at the moment indicated by the timing signal, the bearing in degrees of the ship from the station can be noted from the watch at the moment when the zero signals are received. This bearing can be checked with subsequent zeros. In this method the responsibility for the accurate determination of the bearing rests entirely with the officers of the ship.

As to the reliability of bearings obtained by the methods outlined above errors may arise from two causes; first by mistakes in the estimation of the bearing on the part of the operator of the direction-finding receiver; and second, by the direction of the arrival of the waves at the receiver being distorted from the direct line joining the transmitting and receiving stations. With regard to the first, practice and experience are essential. Assuming that the directional set has been calibrated and the apparatus and aerials are well maintained, the maximum error in fixed stations with practised operators can be taken as 2 deg., and the average error as less than 1 deg. In ships' sets with small aerials the average error is slightly greater. Errors due to wave distortion are negligible by day when the bearings are over water. Bearings obtained during day and from a station suitably placed so that no considerable line of land intervenes can be accepted as reliable if they are competently taken. Bearings over land, unless it is flat, are less accurate than those over water. This is especially the case with night readings. High land close to and between the transmitter and the receiver is a cause of error. Consequently, bearings should not be obtained when a vessel is close to high cliffs.—J. J. Bennett in *Engineering* (London).

How S. A. E. Standards Are Established

THE Council of the Society appoints the personnel of the Standards Committee and assigns to the several Divisions such work as is considered proper. The Standards Committee is presided over by a chairman and two vice-chairmen who are in cooperation with the General Manager of the Society and the Standards Manager, the two last named being located at the Society offices. Each Division of the Standards Committee operates under its own chairman and vice-chairman and considers matters coming within its particular sphere of work. As a rule, when important subjects are to be considered, a Subdivision is appointed; its chairman is a member of the Division and the other members are selected from the Division or from the industry at large, to secure the assistance of the best-qualified men in that particular field. In selecting members of the Standards Committee, great importance is placed on obtaining men of broad experience and, so far as possible, familiarity with standards work. Many of them naturally come from the companies longer established and better known, but these men are, however, selected more for their personal qualifications than because of the company they may represent.

Authentic standards must be formulated from data and other existing information furnished by the industries to a relatively small group of men sufficiently experienced in such work to analyze them and bring, out of the mass experience of many, a well-defined engineering specification. If this process is not carefully guarded, the resulting standard will be a paper one only. Much valuable time will thus be lost directly, by having absorbed the time that might have been profitably spent in some other endeavor. The success of S. A. E. standardization is attributable very largely to the observance of the foregoing conditions and to the fact that the work accomplished is of sound practical nature, presented in such form as to be readily usable by the men in the drafting room and shop in their every-day work.

Initiation and Procedure

The selection of subjects to be considered for standardization is very important. As a rule, they are scheduled at the request or suggestion of an authority in an industry that will be directly affected. They are then studied with relation to the susceptibility of standardization, the limiting features within which standardization can be accomplished and the probable requirements of the industries that will use the standard. Susceptibility to standardization means that the problem must be of an engineering nature and not a commercial exploitation. The limitations are usually those involving the quantity and quality of materials, the dimensioning of parts making for interchangeability and approved methods of procedure. The suggested subject is referred to the Council of the Society for approval and assignment to the proper Division of the Standards Committee. If the subject is involved, it is first considered by the members of the Division to which it has been assigned and a general plan established outlining the features the standard should embody and what formulative procedure should be followed. The industries are then circularized for data representing current practice and suggestions for consideration by the Division. A tentative proposal is next prepared by the Division and circularized for approval or constructive criticism. If, as a result, extensive changes are made by the Division, the revised proposal is circularized before it is submitted to the Standards Committee and the Society.

Decisions

The Standards Committee as a whole meets twice a year to pass upon the reports submitted by the several Divisions. These meetings are open to the Society members, their guests and representatives of companies that may be interested in the reports submitted. The reports are discussed and usually approved in the original or an amended form. In case of disapproval the report is referred back to the Division submitting it for further consideration and presentation at a subsequent Standards Committee meeting. After Standards Committee approval, the reports go to the Council and the Society in meeting assembled. There they may be amended, but they are usually approved as submitted. Reports may, however, be referred back to the Division at either of these meetings. In the majority of cases reports are approved almost unanimously, but where there is a divided opinion the majority rules. After approval by the Standards Committee, Council and Society meeting, the reports are submitted to the voting members of the Society for approval by letter ballot, before they can become official S.A.E. Standards or Recommended Practices. By the time reports have reached this ballot they have been so thoroughly considered by such a large number of interests that the percentage of negative votes is negligible.

The time required to develop a standard varies from a few weeks to in some cases a number of years, depending upon the conditions encountered. A large amount of office work is required in corresponding with the industries and members of the Divisions, arranging meetings, keeping records and maintaining the S.A.E. Handbook. One of the greatest difficulties is to get a sufficient percentage of replies to inquiries for data or the approval of tentative proposals, to represent the opinions and practices of the industries adequately. Much time and unnecessary labor will be saved in all work of standardization if prompt replies are made to such correspondence.

The Handbook

After the work has reached this stage the most important phases of standardization remain, those of publication and distribution. It is essential that all standards be published in a clear, concise and uniform manner. This was recognized in the beginning by the pioneer members of the Society and its Standards Committee and the present well-known loose-leaf S.A.E. Handbook has proved the wisdom of selecting this form of publication. Little need be said beyond the fact that clear drawings in ample detail with tables and notes are used to set forth the standards and recommended practices. A complete set of all these standards goes to all members of the Society and includes the new and revised standards issued twice a year. The complete Handbook is available to non-members of the Society at production cost and a single copy of any standard can be obtained upon request to the Society. The standards are not copyrighted by the Society and are free for reproduction in any technical or commercial publication, with the simple

qualification that the Society be given due credit. Standards and recommended practices are from time to time reconsidered and revised. The procedure is the same as when the subjects were originally considered. It is important to note in this connection that when any extensive operation that involves a standard is contemplated, such as tooling, it is well to ascertain whether that standard has been revised or is under reconsideration.

INTERNATIONAL STANDARDS

THE value of accepted standard dimensions throughout the trade in all branches of manufacture is being recognized more and more every day, and some good work has already been done by the Standardization Committee for the British automobile industry as regards the standardization of tires and rims, which should bear fruit more heavily as the years roll on. In America standardization is much more generally adopted throughout the automotive industry than in this country. In the United States manufacturers are more ready to appreciate the value of such organization and are less conservative than we are, and although this last characteristic of the British people is in many ways gradually being broken down, it is still more or less prevalent among us.

The value of accepted standards is becoming universally recognized, and while we have our Standards Committee of the Society of Motor Manufacturers and Traders at work on English standards, in America the Society of Automotive Engineers has its Standards Committee working out American standards. This committee has done much more than ours, so that many parts are standard throughout the American trade, the dimensions of which in this country differ with every make. Thus in the United States, the wheel track throughout the industry is the same, with the consequence that axles also are all of the same length, with the spring saddles either in one standard position, or adjustable, and, in turn, frame widths are also practically the same, and this uniformity facilitates and cheapens the work of supplies considerably.

Parts and fittings and body makers can standardize on their main dimensions, knowing they will then fit any car, so that not only is the parts-maker saved from finding himself, in the event of losing a customer, with a lot of material on hand that he can use for no one else, but it makes the car manufacturer who buys such parts safer and more independent, as in the event of failure of supply, unsatisfactory quality, or other difficulty arising, he can take the standardized product of another maker and know that the parts will fit into his own chassis plan.

Similarly, the work of the repairer is enormously facilitated, as, in case of an emergency, if parts belonging to the particular make of car are not available, in a large number of cases spares for other cars will either fit or can be adapted with very little alteration. With all axles of the same length, for example, almost any standardized axle could be used to get a broken-down car going again, whereas, with British cars, if a car came in, for example, with a broken 54-in. axle, one of 50 or 52 in., intended for another make, would not be of the slightest use.

In a country like the United States, where the distances are so vast as compared with this country, where by aid of the wire and the rail a new part can be rushed through from the factory in a few hours, this sort of procedure is of great advantage. In foreign countries it is infinitely more so and is, I am sure, a very powerful factor in fostering American foreign trade in cars, while the absence of it hampers our own trade, more especially as the standardization of parts in an individual American car, as apart from their general trade standardization, is as a rule carried much farther than with us, so that not only are spares cheaper and more plentiful, but they usually go in with a less amount of "fitting" than do ours.

Now, it is not wise that British manufacturers should handicap themselves in this matter, and my suggestion is that a strong effort should be made to establish, not only national, but international standards. This could easily be started by cooperation with the Society of Automotive Engineers, each country accepting and adopting the standards independently set up by the other where it has none of its own, and seriously discussing those already adopted by each other, where they clash, with a view to agreement, at the same time working together for the future in all new directions.

The Case of Tires

Take tires, for example. At present we work with the French and make our tires in millimeter sizes, whereas the Americans work in inch measurements. The result is that no English or French standard tire will fit an American car, and no American tire is any use for European machines, so that English makers of tires are compelled to make, not only the European sizes, but the United States sizes as well, or lose a large portion of the replacement trade, not only abroad but in this country. English cars in the Dominions and other far-flung parts of the Empire and elsewhere, often run the chance of finding themselves unable to secure a supply of suitable spares, although there may be plenty of inch-size American tires available, while the agents in those parts have to carry a double stock of tires if they are to be in a position to supply all comers.

Such universal standardization, too, would vastly assist the introducer of new improvements in fittings and accessories and the introduction of such things would be simplified and cheapened. As it is, nearly all new introductions are at once standardized for Fords, because the Ford is not only universal, but Ford owners today form nearly half of the entire motoring community, and, as a consequence, the owners of other cars find themselves unable to obtain many little improved fittings and accessories that the Ford owner has at his command.—Henry Sturmey in *The Motor* (London).

HIGH-SPEED INDICATORS

THE optical indicator developed by the General Motors Research Corporation in its laboratory at Dayton, Ohio, is illustrated on pages 321, 322 and 323 of the TRANSACTIONS for the first half of 1920, vol. 15, part 1. The captions appearing under Figs. 2, 3, 4 and 5 of the paper on High-Speed Indicators by Thomas Midgley, Jr., on these pages and a reference in the text on page 321 indicate that this is the optical indicator of the Bureau of Standards. This error, which was not noticed until after this volume of the TRANSACTIONS was printed, is of course obvious to anyone familiar with the recent developments in indicators since the Bureau of Standards instrument is not of the optical type but employs a diaphragm of the balanced-pressure type in connection with a telephone receiver and an electric contact point, as is described and illustrated on pages 326 and 327 of the said volume of TRANSACTIONS.

Automobile Standardization in Great Britain

By A. A. Remington[1]

THE comparative absence of standardization in the automobile industry in Great Britain, and the high pitch of efficiency to which it has been carried in this industry in America, has frequently been the occasion of comment. It is curious that while in Great Britain we have had for many years the British Engineering Standards Association carrying out standardization of all descriptions for our various engineering industries, automobile standardization has in the past been comparatively neglected, whereas in America, where there has until recently been no equivalent standardizing body, automobile standardization has proceeded apace.

It has been suggested that automobile standardization here would until now have been unwise, as we in Europe, and perhaps more particularly in England, are more individualistic, and that standardization would have had the result of impeding design and causing a general deterioration in quality, but this argument is based on a false conception of what standardization is and what it accomplishes.

THE *Motor Trader* of London, in which the following article appeared, states that there is a distinct tendency toward whole-hearted support of automobile standardization in Great Britain, and that the author is known throughout the industry there to be qualified technically to express an opinion on the matter. Mr. Remington asserts that the fear that standardization may in even the slightest degree result in the hampering of design is absolutely groundless and that the advantages of standardization are inestimable. Practically all of the arguments advanced in the article are not only very familiar to, but have been believed in for many years by, most of the members of the Society, as is obvious from the existence of the hundreds of S.A.E. Standards. In reflecting a gratifying state of affairs with regard to the attitude toward automobile standardization in Great Britain at this time, Mr. Remington gives a forceful and rather comprehensive statement of the principles underlying the conduct of the standardization work of the Society in the last decade.

Result of Industrial Conditions

True, due to the very different conditions obtaining, the effect of standardization would not be precisely the same as in America; the conditions of industry are far from the same, and the needs in consequence different. In America the necessity of obtaining quantity production to fill the factories and of enabling a competitive article to be produced notwithstanding the high rate of wages and also of producing components at specialized factories and assembling them at other plants with the same object in view, in a large measure compelled standardization, and it is probable that the comparatively complete system of standardization was a direct result of the conditions of industry rather than the reverse.

In this country some of the results of the comparative absence of standardization can be seen in the fact that until recently the bulk of the trade has been in the hands of firms with large and ever larger factories, turning out, for the size of the plant, a comparatively small output. The reason is to be found in the necessity for each firm to make all its own parts, and in some cases even its own castings, because, mainly through lack of standardization, its designs and specifications were peculiar to itself, and therefore if it bought the parts outside it was simply a case of giving away all or most of the profit on that part of the turnover. Therefore, as British firms got richer they tended to install more and more plant and more and more departments, so as to keep as much of the profit as possible.

Benefit to the British Industry

At the present moment there is a distinct tendency for the pendulum to swing in the other direction, due possibly to financial conditions, and in consequence we find a tendency to take more interest in standardization. Is it conceivable that the earlier establishment of British automobile standards would have been detrimental, whereas their establishment now will be beneficial? Cooperation between the responsible technical officials of the firms comprising the industry, in a standardization committee, would at any and all times benefit the industry as a whole, and the results of the free cooperation in America in this manner should have the effect of dispelling any fears that may exist that the resulting loss of time at the works and the valuable secret or exclusive information that may be given away operates to the detriment of the individual firm in any way.

Standardization covers several distinct categories, the most important for the automobile being:

(1) The complete standardization of small parts, such as bolts and nuts, pipe unions, greasers and possibly such parts as valves, levers, etc., both as regards dimensions and quality, so that they can be made in large quantities by specialists, at a lower price and more uniformly than would be possible for individual designs and individual firms

(2) The standardization of certain ruling dimensions so that parts not identical in all respects can yet be interchanged, and also so that units will fit when brought together. For example, magneto bases,

[1] F. M. S. A. E.—Past-president, Institution of Automobile Engineers and formerly chief engineer, Wolseley Motors, Ltd., Birmingham, England.

drives and platforms, road-wheel centers and hubs and electrical fittings

(3) The standardization of qualities and tests of materials, so as to avoid the multitudinous specifications, all different, that are otherwise inevitable [illegible] which result in so much confusion and mixing [illegible] erials, with disastrous results at times; the [illegible] ticability of carrying stock with the cer[illegible] of a call for it, and the necessarily high [illegible] occasioned by manufacturing in small quan[illegible] to special orders and specifications

The fear therefore that standardization may in even the slightest degree result in the hampering of design is absolutely groundless. Engineers will, in fact, by suitable standardization be relieved, for good, of much detail work that is now unavoidable, and so have more time and energy left to devote to real design; although perhaps in the earlier committee stage, while our standards are being established, this will not be apparent, as the work will at first occupy a considerable amount of the time of our engineers. This, however, must be faced, as it was, and still is, in America, well knowing that the immediate advantage of cooperation is by no means inconsiderable and the ultimate advantages of the resulting standardization inestimable.

In considering the possible advantages to be gained by standardization, would anyone today suggest that the standardization of screw pitches and form by Whitworth was anything but good? Yet there was a time when engineers of a certain school thought it in their interests not to use the standards, and Whitworth did not get the interest he deserved taken in his standardization schemes for a long time.

If the same attitude prevails in any quarters today, it may be of interest to take a few concrete cases out of the many that are sure to come before our various committees in the near future.

A Means to Lower Prices

Is there any risk of the fettering of design, should a committee of first-class technical men meet and settle, once and for all, the best material or materials for piston-rings, and the best dimensions and tolerances for rings of different diameter, so that in the future all makers using a ring of a certain diameter can use identical rings of the most suitable material and proportions, as decided by those best qualified to judge; will be able to buy these rings at a lower price than they could make them for, because they will be made in larger quantities; will get better deliveries, because they will be made for stock; and will be relieved of all the trouble and expense of design, experiment and research in regard to this detail in the future?

A number of parts come in a similar category, parts for which there is a correct proportion depending on unalterable conditions, and where individuality in design is only the result of ignorance due principally to a lack of analysis and research, and is in reality only a relic of rule-of-thumb methods.

Of course, the committee would meet from time to time after the establishment of the standards to insure their being kept uptodate in regard to new sizes and such matters.

Can anything but good result from the standardization of qualities and tests for materials at the hands of committees composed of the men having the best knowledge of the materials in question, their qualities and uses? This class of standardization, as already pointed out, does not tie the designer's hands but puts before him clearly in specification form what materials of the class he considers he requires are obtainable, and what results can be expected from them, without his having to search the markets and make a choice from many materials, all perhaps slightly different, any of which would meet his requirements.

An Example of Its Effect

The ways in which standardization helps industry are multitudinous, but let one more example suffice. Standardized materials put all suppliers on an equal basis for comparison, and so bring the question of efficiency to the fore, and it will be found that quality and uniformity or reputation will tell more than ever, because the user will be able to compare the goods he buys on an equal basis, and there will therefore be no tendency for standardization to have the effect of only permitting the just-good-enough at the lowest price to suffice.

Now that interest is reawakened in automobile standardization, late though it may be, it is to be hoped that all will do their best to make up for lost time and do all in their power to assist forward the good work by either practical or moral support. Many engineers and technical experts will be found only too willing to assist, and it is to be hoped that their efforts will not be frustrated by lack of support and facility, occasioned by the fear of partial loss of individual services at the works or of a certain amount of so-called exclusive information on the part of their employers.

The aircraft industry set a great example in the war under a pressing necessity, and the automobile industry is today, perhaps to a large extent unknowingly, benefiting from this work; but many of the specifications are not directly applicable to the automobile, although they are capable of forming a most useful basis and so of saving the automobile standardization committees an enormous amount of time and trouble. The fact of carrying out this work through the British Engineering Standards Association will render all this knowledge available to the automobile committees as well as give them the benefit of all the knowledge accumulated by the Association as to the best way of carrying out this sort of work.

SIMPLIFICATION

SIMPLIFICATION is probably one of the most important means of cutting production cost, but it cannot be accomplished by the individual manufacturer without the whole-hearted support of the financial, sales and production executives. To obtain the greatest reduction in cost it is necessary that such simplification be carried beyond the plant of the individual manufacturer, until, by cooperative effort, a National simplification is accomplished that will react with tremendous advantage to each manufacturer. Such cooperative simplification, or standardization, between manufacturers is carried out most advantageously by trade organizations.

Decreasing Production Costs Through Standardization

By W. D. Pardoe[1]

THE author relates experiences concerning actual benefits obtained by standardization in manufacture in the plant that he manages. The instances cited include clutch facings, brake blocks, radiator hose, tire sections furnished as tire samples to dealers, tire sizes, brake-lining and flexible-coupling discs. The methods used in classifying and standardizing are recounted and the resultant improvements due to this and to S. A. E. Standards are stated in connection with each product.

The savings in cost are indicated, as well as other benefits. The possibilities of further standardization along the same lines are said to be almost unlimited. It is recommended that a standard test for brake-lining be developed, a further desideratum being that costs be decreased by the use of more efficient methods of manufacture and the introduction of labor-saving machines, rather than by lowering the quality of the raw materials used in the fabrication of the product.

OUR inventory of 1918 disclosed that we were fabricating 145 different articles, but that our production of some of them was so small and our margin of profit so slight that it was obvious that they were being manufactured at an actual loss. We found that we were making approximately 170 different sizes of clutch facings and brake blocks; the majority in small lots for individual customers. Each size in the process of manufacture, however, necessitated individual mold equipment and a substantial investment therein. It was evident that some steps should be taken to standardize the sizes of clutch facings, especially as there was only a slight variation in the outside and inside diameters and the thickness of many sizes. Many of the differences in thickness, though very slight, did not permit standardization of the thickness of the material, requiring a resetting of the cutting machines, owing to the variation of the flange width and other production elements, with the resultant decreased production volume.

The facing sizes have now been classified into active and inactive groups. We, of course, do not venture to say that we will not make this or that size of facing because it happens to be in the inactive group and therefore not standard with us, but we try to determine the cost of production before making our decision. We have found that when we outline to a customer that it is to his advantage to use a standardized product, in the majority of instances he is willing to accept it in preference to a non-standard article. The Transmission Division of the Society recognized this situation and has formulated a recommendation[2] which will be submitted for consideration at the Standards Committee meeting in January. The adoption of this recommendation will aid greatly in the solution of the individual standardization problems of all companies manufacturing clutch facings for single-plate and multiple-disc clutches.

[1]Factory manager, Thermoid Rubber Co., Trenton, N. J.

[2]This recommendation is printed in this issue of THE JOURNAL on page 433.

[3]This recommendation is printed in this issue of THE JOURNAL on page 432.

Clutch Facing Standards

The Transmission Division proposes the adoption of 18 sizes of multiple-disc facing and 6 sizes of single-plate facing, making a total of only 24 sizes, as compared with 45 sizes that were previously used in different clutches. If these standard sizes are adopted, this will result in a reduction of the capital invested in mold equipment, greater production and demand and a better and more uniform product. This will be reflected in reduced costs to the clutch manufacturer.

Standardization of parts and materials permits the simplification and the standardization of each operation in their manufacture. The operator becomes more skilled in the performance of any given operation, owing to greater experience in longer runs; less time is lost in changing over the machines for special work and the cost of production is reduced materially as a natural consequence.

Standardization has enabled us to increase our radiator-hose production threefold with exactly the same equipment. Prior to the inauguration of our simplification program, we made a great variety of styles, lengths and sizes of hose. Much of the increased production obtained is due to the elimination of the necessity of changing over the machinery to produce first one size and then another. Prior to this standardization of radiator hose, an automobile manufacturer induced us to make hose with the name of the car molded on each piece. This not only increased the cost, but slowed up production to such an extent that we were unable to make prompt shipments.

As an example of the savings realized by standardization even in the case of samples, we found that tire sections furnished to dealers were not standardized as to length. Some of our dealers required a 4-in. section, others a 5-in., while still others were not content unless they were furnished with 6-in. sections. The object in having the longer samples was to show the non-skid design of the tread, but this could be shown by photographs and the shorter section would show the thickness of tread, number of plies of fabric and other details of construction. We standardized on a 2-in. section for the non-skid and a 1-in. section for the ribbed tread, which resulted in a saving that has amounted to $5,000 per year.

Tire Standardization

During the war, through the efforts of the War Industries Board in cooperation with the Rubber Association of America and tire manufacturers, odd-size tires were practically eliminated. Table 1 shows the sizes that were called for and considered more or less standard sizes in 1917. As a result of this wartime standardization and subsequent standardization by the Society of Automotive Engineers and other interested organizations, the list of standard pneumatic-tire sizes will be reduced to 9 sizes for passenger cars and 9 for motor trucks in case the recommendation[3] of the Tire and Rim Division

is favorably acted upon at the January Standards Committee meeting.

TABLE 1—NOMINAL TIRE AND RIM SIZES USED IN 1917

28 x 3	32 x 4	34 x 4½	36 x 5
30 x 3	33 x 4	35 x 4½	37 x 5
30 x 3½	34 x 4	36 x 4½	37 x 5½
[illegible]½	35 x 4	37 x 4½	38 x 5½
[illegible]½	36 x 4	33 x 5	36 x 6
[illegible]½	32 x 4½	34 x 5	38 x 7
4	33 x 4½	35 x 5	40 x 8

try to discourage the sales of non-standard tires by making them non-cancellable. This tends to reduce such sales, and eventually the salesmen will not push a non-standard size because of the sales resistance. Again, we have less mold equipment, less capital involved and less confusion in manufacturing, which is a distinct advantage from the production standpoint.

Much has been done in the way of the standardization of manufactured products, but the possibilities of further work in the same direction are almost unlimited. The S.A.E. Standard for brake-lining[4] specifies both the width and the thickness tolerances. As long as we manufacture to these tolerances, every operation runs efficiently. However, when we receive an order for 16,000 ft. of 2 x 3/16-in. brake-lining not to vary more than 0.005 in., we must start with the preparation of special asbestos-yarn and the manufacturing department must follow this particular order through in detail, giving very careful attention to the weaving, frictioning, making, rolling and pressing of the lining. When finished, it must be given painstaking inspection. All of this special attention requires time, increases the cost and affects production seriously.

Brake-Lining Tests

Standard methods of testing are very desirable in that both manufacturer and customer can check the product furnished. Practically all manufacturers now use methods developed in their own laboratories for testing brake-lining; and of the many machines used for this purpose no two are alike, so that it is impossible to compare results obtained in different laboratories. Inasmuch as standard methods for the testing of steel, cement and other materials have been developed satisfactorily, why should not a standard test for brake-lining be developed? Believing that this is feasible, the Society's Subdivision on Brake-Lining, working in conjunction with the Bureau of Standards, has had several meetings to develop a machine that will be inexpensive and at the same time give the desired information. The results obtained to date indicate that in a short time a satisfactory standard method will be adopted.

Flexible-Coupling Discs

Standardization of flexible-coupling discs should receive serious consideration. Our company has mold equipment for at least 500 active sizes of only slight differences, some having the same outside and inside diameters and thicknesses, but different bolt-hole circles. The Society's Parts and Fittings Division at its September meeting reported the possibility of recommending a complete list of sizes increasing in diameter by ½ in., with two or three thicknesses for each diameter. If this proposed standardization could be carried through, it would assist very materially the manufacturers of this part.

[4]See S. A. E. Handbook, vol. 1, p. C55.

At the beginning of this article I stated that we had been making 145 different articles. We are now producing 35, and there is possibility of further simplification; for example, by the standardization of flexible-coupling discs. We appreciate that all of these parts cannot be standardized at once; time and careful study are required to accomplish the results desired.

Conclusion

During the present period of price readjustment and keen competition, it is important, in fact imperative, that every manufacturer, whatever his product may be, decrease costs. This should be accomplished by the use of more efficient methods of manufacture, and the introduction of labor-saving machines, rather than by lowering the quality of the raw materials used in the fabrication of the product. The importance of standardization as a means of reducing manufacturing costs, of obtaining greater production at less cost, and of attaining a higher quality of goods with less rejections due to defective manufacture, cannot be overestimated.

THE NATURE OF MAN

EACH generation of beavers begins where the preceding generation began; that is a law for animals; there is no advancement, no time-binding, a beaver dam is a beaver dam. Contrast this with human life. Man invents and discovers and creates. An invention or discovery or creation once achieved, what happens? Each invention leads to new inventions, each discovery to new discoveries, each creation to new creations; invention breeds invention, science begets science, the children of knowledge and art and wisdom produce their kind in larger and larger families; each generation begins, not where its predecessor began, but where it ended; things done become instruments for the doing of better things; the Past survives in the living achievements of the dead; the body of these achievements, invention, science, art, wisdom, is the living capital of the ever-passing Present, inherited to be held in trust for enlargement and for transmission to Future man; the process is that of time-binding: Past and Future are thus united in one eternal Now owning a law of perpetual growth and continual progress. What is the Law thereof, the natural Law? You see at once what it is; it is that of a rapidly increasing geometric progression. If P be the progress made in a given generation, called the first, and if R be the ratio, then the progress made in the second generation is PR, that in the third PR^2, and that made in the single Tth generation will be PR^{T-1}. Observe that R is a large number and that the time T enters as an exponent, and so the expression PR^{T-1} is called an exponential function of Time. This is an amazing function; as T increases, the function not only increases but does so at a rate that itself increases according to a similar law, and the rate of increase of the rate of increase again increases in like manner, and so on endlessly, thus sweeping on toward infinity in a way that is truly marvelous. Yet that is the law, the natural law, for the advancement of civilization—, immortal offspring of the marriage of Time and human Toil.

The World War was an unforeseen, sudden, cataclysmic demonstration of human ignorance of human nature, a demonstration, pitiless as fate or famine, that human beings have never rightly conceived Man to be what Man is, not a mixture of natural and supernatural nor a species of animal, but the natural agency for those time-binding energies in the world whose peculiar function it is to produce civilization and to do so in conformity with its marvelous law of an increasing function of time.—From an address by C. J. Keyser before Phi Beta Kappa Society, Columbia University.

THE TRUTH ABOUT COMMERCIAL AVIATION

THERE has been on the topic of aerial transportation so much false optimism on one hand and so much needless pessimism on the other that the average person is somewhat bewildered as to whether aviation is coming or going.

The Society, whose membership includes so many of the foremost American designers of aircraft, will hold a series of meetings through its Sections in several cities during the present month at which various speakers will tell what has actually been done both here and in Europe in the way of commercial aviation. Authoritative figures will be given showing the number of planes now in operation, the number of miles flown during the past year, the percentage of successful flights and the number of accidents to planes attending to business as contrasted with the much greater loss of life and limb caused by spectacular stunting or through the use of imperfectly designed machines or the operation of planes by insufficiently trained pilots.

The cost of aerial transport per passenger-mile and per ton-mile will be given. These figures will be obtained from flights that have actually been made on regular schedules both here and abroad.

Reports indicate that the machines of one foreign manufacturer during the past summer made 693 out of 725 trips scheduled; over 95 per cent. More than 160,000 miles was flown with no accidents whatever to cargo or passengers.

The annual report of our own Air Mail Service involves a much greater mileage. Of 7659 trips planned, 7081 were perfectly completed, or 85 per cent. Nearly half of the flights were made under bad weather conditions. A million and a half miles was flown and about 45,000,000 letters were carried.

After recounting what has been done to date, those scheduled to give the talks at the various meetings will discuss what problems are still to be solved. Subjects that will receive attention in this connection are airways, landing-fields, ground organization, legal aspects, radio and meteorological service and the relation of civil aviation to national defense. In connection with this last subject moving pictures will be shown of the recent aerial bombing operations against the surrendered German battleships. These pictures have not previously been shown publicly.

Those who will take part in this national program include J. G. Vincent, conspicuously identified with the Liberty engine; Glenn L. Martin, one of the pioneers in aviation; Ralph Upson, balloon expert; and Assistant Postmaster General Shaughnessy, who will give real information about the Air Mail Service.

The following dates have been fixed definitely:

St. Louis	Dec. 1
Detroit	Dec. 5
Indianapolis	Dec. 12
New York City	Dec. 15
Boston	Dec. 16
Cleveland	Dec. 16
Philadelphia	Dec. 22

Other meetings will be held at San Francisco, Buffalo, Los Angeles, Cincinnati, Detroit and Chicago.

International Aero Congress

The Society was officially represented at the International Aero Congress held at Omaha, Neb., on Nov. 3, 4 and 5, by Past-President Howard E. Coffin. In the Pulitzer Race the World's record was broken by several miles, the speed being officially given as over 176 m.p.h. Planes flew to this meeting from practically every section of the Country, and many thousand people were on the grounds during the competitions.

The sessions of the Congress were devoted largely to consideration of the formation of a national aviation body, and the presentation and discussion of reports and resolutions. Final steps were taken in the formation of the National Air Association, the following officers being elected: President, Sidney D. Waldon, Detroit; First Vice-President, Col. R. S. Hartz, City of Washington; Second Vice-President, Eddie Rickenbacker; Third Vice-President, Albert Pond, Lambert, N. Y.; Recording Secretary, Rex L. Uden, Cleveland. A board of governors to consist of 18 men, two from each of the nine Army Corps areas, was created. A committee was appointed for the purpose of discussing with the Governing Committee of the Aero Club of America the possibility of effecting a consolidation between it and the new association.

ON THE R38 DISASTER

AT intervals in the course of every human effort toward progress, moral or physical or mechanical, there befalls a disaster which arrests the attention of the world and causes the faint-hearted to regard it as the end of all things. In reality these disasters cause a temporary check, but ultimately they do good in that they act as a spur to further effort because man will not acknowledge defeat and they provide valuable lessons in what to avoid in the future.

Thus the burning of the Amazon on her voyage to America made many people fear steamship travel. But it made the builders of steamships more determined than ever to succeed, and it taught them valuable technical lessons. Similarly the burning of the Irish Mail train at Abergele caused some people to exclaim that here was the end of these dangerous high-speed expresses. Yet all it did was to lead to improvements in couplings and signals and to improve the running of railroads generally. And the burning of the German Navy's Zeppelin L2, though it frightened those who did not believe firmly in airships, only spurred the German Navy and the Zeppelin company to greater efforts, with results that we in England can appreciate better than anybody else.

It was known that certain girders of the R38 were weak. It was known that the ship "hunted" at certain speeds; that is to say she tried to dive and then tried to rise in successive waves in opposition to her elevator control, which would naturally strain her girder-work. It seems fairly clear, therefore, that either under rudder or elevator strain her girder structure failed.

Naturally the hull would crumple in consequence. The crumpling of the hull would tear or burst the adjacent gasbags and gasoline tanks. The gas, either hydrogen or gasoline or both, would mix with the air and the resultant explosive mixture would be almost bound to catch fire from the engine exhausts, for the men in control of the engines would hardly have time to realize that something was wrong and to stop the engines before the explosion would occur.

In the ordinary way, escaping hydrogen or gasoline, if set on fire, burns and does not explode, as those who have seen burning Zeppelins and kite-balloons know. L2 at Johannisthal, which caught fire in the air, burned but did not explode. Therefore the gas must have been gushing out and mixing with air for some time before it caught fire; which proves fairly conclusively that the breaking of the ship caused the fire and that the fire did not cause the breaking of the ship.

Those facts are at any rate almost indisputable. It would be unsafe and perhaps unfair to hazard any further opinions until the Air Ministry Enquiry Committee publishes its report. Then possibly some new evidence may be forthcoming. In any case it is likely that knowledge of value may be obtained, for it has frequently occurred in the past, in connection with airplane as well as airship accidents, that although exact proof of the cause has been lacking various possible causes have been suggested, which suggestions have led to improvements and alterations of great use thereafter.—*The Aeroplane* (London).

OCTOBER COUNCIL MEETING

THE session of the Council held in Cleveland on Oct. 21 [illegible] nded by President Beecroft, First Vice-President Horning, Vice-Presidents Bachman, Johnston and Van [illegible] cilor Martin, W. R. Strickland, J. V. Whitbeck. [illegible] man, E. W. Weaver and O. A. Parker. Presi- [illegible] t addressed the members of the Cleveland Sec- [illegible] ening meeting.

[illegible] ngs Committee reported on the progress it is [illegible] lans for coming meetings of the Society. There was considerable discussion of the series of sessions on civil aviation to be conducted during December by several Sections of the Society and by members in cities where there are no Section headquarters, including St. Louis. A resolution was passed favoring the enactment of the bill introduced by Senator Wadsworth in Congress to create a Bureau of Civil Aeronautics in the Department of Commerce.

Thirty-nine applications for individual membership and five for student enrollment were approved, as well as the following transfers in grade of membership: Member to Service Member, Capt. George E. A. Hallett, Gordon Pennington, Edward A. Sipp; Associate to Member, W. C. Barry, Edward Ropp, F. B. Sexton, E. E. Stephens; Junior to Member, E. A. Ryder, William Taylor, Edgar S. Gorrell; Junior to Associate, J. L. White, J. C. Georg, Melvin Rae Wilcox, Arthur Brandes, A. K. Fleming, Ralph Earl Hitchcock, Reuben Kuempel, James L. Myers, Thomas S. Wilson, Richard T. Robinson, Jr.

Thirty-seven applications for membership were received during September as compared with 88 for the same month of 1920. On Oct. 17 there were 5564 on the rolls of the Society, including affiliate member representatives and enrolled students, as compared with 4994 on the same day of 1920.

Subjects Assigned to Standards Committee

Subjects were assigned to respective Divisions of the Standards Committee, as follows:

Emergency Rim-Clamps and Passenger-Car Front-Axle Hubs—Axle and Wheels Division
Breaker Contacts, Generator Strap-Mounting and Magnet Wire—Electrical Equipment Division
Crankcase Drain-Plugs—Engine Division
Tail-Lamps—Lighting Division
Solders—Non-Ferrous Metals Division
Wing Washers—Parts and Fittings Division
Hand Taps and Wing Nuts—Screw Thread Division
Industrial Truck and Tractor Batteries—Storage Battery Division
Three-Joint Propeller-Shafts—Truck Division

Research Matters

In connection with the Research Department, it was reported that it had appeared advisable to complete a general survey of the present research activities and facilities at the disposal of the Society, enough having been accomplished in the preliminary survey to indicate rather clearly the most pressing needs of the Society that can be met by the Department. There is now in progress in a number of laboratories, including those at Massachusetts Institute of Technology, University of Michigan, Sheffield Scientific School, University of Illinois and University of Nebraska, a large amount of very valuable and creditable research that has not come to the attention of the members. Moreover, an unexpected amount of valuable information that has not been made public has been obtained from time to time through researches in the various industrial laboratories. The most immediate need seems to be a more convenient and effective means for the individual engineer in either research or development to learn what has been done and is being done in his own particular line. To this end, the Research Department will make a careful canvass of all research laboratories and all individuals who have information to impart, the purpose being to establish in the office a complete index of projects under way and completed but not published.

The real business of the Research Department is to organize research in such a way as to meet the needs of the industry, and the ultimate aim is to draft a comprehensive program of needed research, to check against this the work already undertaken that shows promise of success, and secure the initiation of such additional researches as may be needed wherever the best facilities are to be had. The first portions of this general program will involve the two general problems of fuels and highways. With regard to the former, a tentative program for the study of the relations between fuel volatility and total consumption was approved by representatives of the American Petroleum Institute and the Society some months ago. This is one phase of the fuel problem that should be undertaken as soon as possible. Considerable very active highway research is in progress at a number of institutions. The Research Department has been asked to take part in laying out a program for the study of highway tractive resistance to be conducted by the Massachusetts Institute of Technology and at Yale University.

ENGINEERING'S VIEW

THAT a proper system of standardization would cheapen motor-car production requires no demonstration. The matter is obvious. We are not prepared to say that the more standardization the more benefit. It would, no doubt, be possible to go too far, but in the early stages certainly the more standardization the more benefit. If steel for leaf springs alone is standard the manufacturer may possibly be required to roll only 10 sections instead of 60. He can thus roll it more cheaply, and it can be bought and sold more cheaply. It would reduce the price of British cars; not much certainly, but cheapness in repetition manufacture is partly obtained by concentrating on details. If brake-shoes were then standardized one would have the cheapening of a further item, and the process could with profit be carried very far.

As the motor-car industry first developed in this country it was largely in the hands of enthusiasts, who were not always engineers, and the value of individuality in car design became over-accentuated. This point of view persists even to this day, and too many makers appear to think that some extra virtue lies in the use of a distinctive detail for which a standard part would be an entirely satisfactory substitute. For a very limited trade and a very limited class of car there is something to be said for the peculiar detail, but if the automobile industry is to take the place its importance deserves in the range of engineering manufacture, it must be realized that the best machine at the lowest price are qualifications far outweighing the value of five-sided nuts or any other distinctive features of such minor importance.—*Engineering* (London).

Reports of Divisions to Standards Committee

THE Division Reports enumerated below will be presented at the Standards Committee Meeting, Tuesday, Jan. 10, beginning promptly at 10.30 a.m. on the fifth floor of the Engineering Societies Building, 29 West 39th Street, New York City. They are published in this issue of THE JOURNAL, sufficiently in advance of the Standards Committee Meeting to permit a careful review of the recommendations and the preparation of discussion by the members of the Standards Committee and others who expect to be present. The reports of the Divisions will be presented at the Standards Committee Meeting in the order in which they appear hereinafter. Discussion of the reports at the Standards Committee Meeting and at the Society Meeting that follows is invited from all who are technically familiar with the several subjects, whether or not they are members of the Standards Committee. All discussion should be to the point and as brief as possible, owing to the limited time available at the meetings for such presentation.

Under the Standards Committee Regulations only members of the Standards Committee may participate in the voting that will follow the discussion of each recommendation at the Standards Committee Meeting. At the Society Meeting only qualified voting members of the Society may participate in the voting.

All subjects passed at the Standards Committee and Society Meetings will be reported in the February issue of THE JOURNAL and submitted to a letter ballot of all the voting members of the Society, unless contrary direction is given by the Council.

The several Divisions submitting reports, and the Subdivisions which in many instances prepared them, have carefully considered their subjects and the conditions bearing on them. It should be borne in mind that the recommendations have been founded on data obtained directly from the industries, but are necessarily compromises in greater or less degree of current practice by individual companies, and involve what may be considered ideal practice so far as this is practicable. It should be understood also that the recommendations need not necessarily be put into practice upon their adoption by the Society, but should be followed by the various industries when changes in design or production make it economically possible to do so.

The members of the Standards Committee, who are selected because of their broad experience and ability to represent adequately the many branches of the automotive industries, have given generously of their time and resources for the standardization work during the past year in face of the serious conditions that have existed. This truly indicates the recognized value of standards, and makes it practically necessary for the managers and executive directors of the industries to keep informed of the work being done by the Society, and to give it due recognition and support by having the standards used in their products as extensively as possible. The manufacturing and sales executives are urged to review the recommendations of the Standards Committee, to bring their points of view to bear in the discussion at the meetings and to facilitate the work of the engineers in the manufacturing of their products by having the standards used as extensively as possible.

AERONAUTIC DIVISION REPORT

TACHOMETER DRIVE

(Proposed Revision of Recommended S.A.E. Practice)

Experience has indicated that the driving element in the present recommended practice, page C75, S.A.E. HANDBOOK, for the tachometer-drive connection at the engine is not strong enough to prevent binding in the tubing due to the tendency of the flexible driving-shaft to untwist, especially in the operation of types of tachometer which turn faster than indicated speed. The Division therefore recommends that the present S.A.E. Recommended Practice for Tachometer Drive be revised as follows:

(1) Change the diameter of the tachometer driving-shaft from 0.152 plus or minus 0.001 in. to 0.187 plus or minus 0.001 in.

(2) Change the drill size for diameter of the hole for the tachometer driving-shaft from No. 20 (0.161 plus or minus 0.002 in.) to No. 11 (0.191 plus or minus 0.002 in.)

BALL AND ROLLER BEARINGS DIVISION REPORT

ANNULAR BALL BEARINGS

(Proposed Revision of S.A.E. Standards)

Last summer a complaint was received from a user that it was difficult for manufacturers building parts to be fitted with ball bearings to secure bearings having bores ground to a sufficiently narrow range of tolerance to obtain the proper fit and interchangeability of bearings on accurately ground shafts.

A Subdivision appointed to investigate this matter reported that accurate measurements made on a number of bearings from each of the different manufacturers as secured on the open market showed that the variation from the nominal inside diameter in practically all cases is from the nominal to about two-thirds of the minus limit, and seldom, if ever, on the plus side of the nominal diameter.

It is felt that as practically all ball bearings used by the automotive industries are made to within a narrower range of bore tolerances than specified in the present standards for annular ball bearings, the tolerances can be lessened without creating any difficulties for the bearing manufacturers.

The Division, in studying the report of the Subdivision, considered it desirable to rearrange somewhat the distribution of the tolerances over the ranges of bearing

TABLE 1—INSIDE DIAMETER TOLERANCES RECOMMENDED

Range of Inside Diameters, mm.	Tolerances, in. Plus	Minus
4 to 25	0	0.0004
30 to 55	0	0.0005
60 to 80	0	0.0006
85 to 110	0	0.0007
120 to 210	0	0.0008

sizes to provide more logical increases in grinding limits with the increases in the diameter of the bore. It is therefore recommended by the Division that the plus tolerance on all types of annular ball bearings be omitted and the tolerances redistributed over bearing bores as Table 1.

recommendation applies to the following S.A.E. ls for annular ball bearings, printed on the S.A.E. HANDBOOK pages indicated:

ılar Ball Bearings, Light Series	C26
Annular Ball Bearings, Light Series, Extra Large	C27
Annular Ball Bearings, Medium Series	C28
Annular Ball Bearings, Medium Series, Extra Large	C29
Annular Ball Bearings, Heavy Series	C30
Annular Ball Bearings, Wide Type	C31
Annular Ball Bearings, Separable Type	C32
Annular Ball Bearings, Extra Small Series	C33
Annular Contact Ball Bearings, Medium Series	C33a
Annular Contact Ball Bearings, Medium Series	C33b
Annular Contact Ball Bearings, Heavy Series	C33c

CHAIN DIVISION REPORT

ROLLER-CHAIN SPROCKET-CUTTERS

(Proposed Extension of S.A.E. Standard)

The Chain Division recommends the following for adoption as an extension of the present S.A.E. Standard for Roller-Chain Sprocket-Cutters as the importance of standardizing sprocket-cutters so as to make it possible for sprocket-cutter manufacturers to carry in stock a single type of cutter which will cut all sizes of standard sprockets is realized.

Two straddle cutters shall be used, an *A* cutter having an average pressure-angle of 23 deg. for use where the arc of contact between the chain and the sprocket is fairly large, and a *B* cutter having an average pressure-angle of 17½ deg. for use only where the arc of contact is small.

All cutters shall be marked with the pitch, roller diameter and the range of the number of teeth for which each cutter is designed.

The inside and outside diameters and the keyway dimensions of sprocket-cutters shall be in conformity with the dimensions specified in Table 2.

Standardization of the inside diameter of sprocket-cutters is considered important as determining the diameter of the arbor used; and of the outside diameter because, if too small, the cutter is liable to break in service. The use of too large an outside diameter results in a waste of material and requires more time for cutting the work. The Division gave some consideration to the advisability of standardizing the number of gashes in the sprocket-cutter, as too many gashes decrease its life. It is felt advisable, however, to leave this to the cutter manufacturers so as not to limit individuality of design. The cutter-arbor keyways recommended for adoption are in accord with the standards used by machine-tool builders.

The Division's recommendation for straddle-cutters was made after careful consideration of the relative merits of straddle and space-cutters, one point being that a space-cutter used, for example, on sprockets having 12 teeth would cut teeth with flat crowns, while on sprockets having 17 teeth it would cut teeth with pointed crowns.

In Table 2 the roller diameter and cutter bore dimensions were calculated from the following formulas:

$$RD = 1.2(B + RD + 0.7\,P) + 1$$

$$B = 0.7 \sqrt{(W + RD - 0.7P)}$$

where

B = cutter bore
P = pitch of chain
RD = roller diameter
W = width of cutter

TABLE 2—PROPOSED SPROCKET CUTTER DIMENSIONS

Pitch, in.	Roller Diameter, in.	Cutter Bore, in.	Keyway, in.	Cutter Outside Diameter, in.
⅜	0.200	1	5/32 × 5/64	2¾
½	0.250	1	5/32 × 5/64	2⅞
½	0.250	1	5/32 × 5/64	2⅞
½	0.313	1	5/32 × 5/64	3
⅝	0.313	1	5/32 × 5/64	3⅛
⅝	0.400	1	5/32 × 5/64	3¼
¾	0.400	1	5/32 × 5/64	3⅜
¾	0.469	1	5/32 × 5/64	3⅜
1	0.469	1	5/32 × 5/64	3½
1	0.563	1¼	3/16 × 1/2	4
1	0.625	1¼	3/16 × 1/2	4⅛
1¼	0.625	1¼	3/16 × 3/32	4¼
1¼	0.750	1¼	3/16 × 3/32	4⅜
1¼	0.750	1¼	3/16 × 3/32	4⅝
1½	0.875	1¼	3/16 × 3/32	4¾
1¾	0.875	1¼	3/16 × 1/2	5
1¾	1.000	1½	3/16 × 5/32	5½
2	1.000	1½	3/16 × 5/32	5⅝
2	1.125	1½	5/16 × 5/32	5⅞
2½	1.125	1½	5/16 × 5/32	6¼
2½	1.550	1¾	3/8 × 3/16	7⅛
3	1.550	1¾	3/8 × 3/16	7½
3	1.900	2	1/2 × 1/4	8¼

ROLLER CHAINS

(Proposed Extension of S.A.E. Standard)

The Chain Division recommends that the present S.A.E. Standard for Roller Chains be extended to specify the minimum breaking-strengths based on the formula

$$\text{Minimum Breaking-Strength in Pounds} = 105{,}000\ (\text{Pin Diam.})^2 - 700$$

It is known that well constructed roller chains will withstand heavier pulling loads than those indicated by this formula, but the Division desires to specify the *minimum* breaking-strengths in order that users having a limited knowledge of the proper application of roller chains may have a reliable guide as to proper chain applications. The factor 700 is included in the formula because the case-hardening of the pin has been found by tests to reduce the strength against shearing by about this amount.

The actual minimum breaking-strengths for the light, medium and heavy series of S.A.E. Standard roller chains calculated by the formula recommended are given in Table 3.

TABLE 3—MINIMUM BREAKING-STRENGTH OF S.A.E. STANDARD ROLLER CHAINS

HEAVY SERIES		MEDIUM SERIES		LIGHT SERIES	
Chain Number	Minimum Breaking-Strength, lb.	Chain Number	Minimum Breaking-Strength, lb.	Chain Number	Minimum Breaking-Strength, lb.
30W	940				
40W	1,850	41W	940		
50W	3,500	51W	1,850	52W	940
60W	5,045	61W	3,500	62W	1,850
80W	9,550	81W	5,045	82W	3,500
100W	14,063	101W	9,550	102W	9,045
120W	19,400	121W	14,063	122W	9,550
140W	25,550	141W	19,400	142W	14,063
160W	32,520	161W	25,550	162W	19,400
200W	63,350	201W	32,520	202W	25,550
240W	91,585	241W	63,350	242W	32,520
320W	163,360	321W	91,585	322W	63,350
400W	285,550	401W	163,360	402W	91,585

The Chain Division also recommends that the thickness of center plates for double, triple and quadruple chains shall be equal to twice the thickness of the inside plates in S.A.E. Standard single roller chains.

ELECTRICAL EQUIPMENT DIVISION REPORT

Insulated Cable

(Proposed Revision of S.A.E. Standard)

The letter ballot of the Society members last July on the adoption of the revised S.A.E. Standard for Insulated Cable, page B33, S.A.E. Handbook, as approved at the Standards Committee Meeting last May, afforded some constructive criticism by one or two members which has since been considered by the Electrical Equipment Division in the preparation of the recommendation now presented.

Criticism was made of cleansing the copper wires in a caustic-alkali solution or hot water and soap, it being contended that such treatment leaves the wire in condition to be attacked by the sulphur in the rubber insulation. As neither of these cleansing solutions is used to any extent, it is thought advisable to exclude them from the specification, and to include carbon tetrachloride which is used frequently.

The Division also recommends that the strength of the sodium-polysulphide solution be definitely specified to prevent the use of a saturated solution, and to make the specification more definite. The remainder of the Division's recommendation includes changes in the present specifications that will eliminate extraneous matter and generally improve the standard.

The recommendation of the Division for revision of the present standard, is:

Section II—Tests

Par. 1—Omit the terms "caustic-alkali solution" and "hot water and soap" and insert the term "carbon tetrachloride." Add the sentence "Care shall be taken to avoid abrasion or scratching of the samples of wire to be tested."

Par. 2—Insert the phrase "having a specific gravity of 1.142 at 70 deg. fahr. (21 deg. cent.)" after the words "sodium polysulphide." In the last sentence omit the words "and which has" and begin a new sentence reading, "The polysulphide solution shall be maintained at a ———".

Par. 4—Omit the second sentence reading, "All wires shall withstand one immersion in the hydrochloric acid without blackening in the sodium-polysulphide solution, and 75 per cent of the wires shall withstand three immersions in the hydrochloric acid without blackening in the sodium-polysulphide solution." This part of the present specification will be covered in the two preceding paragraphs of the standard.

Par. 5—Add the following sentences as Par. 5, "After completing the above operation the samples of wire shall be examined to ascertain, through blackening caused by the sodium-polysulphide solution, whether the copper is exposed. The samples shall be considered to have failed if by such blackening the copper shall be shown to be exposed."

Footnote—Add a footnote referring to Section II—Tests, reading, "This test conforms substantially to that in American Society for Testing Materials Specification B33-19T."

Generator Flange Mounting

(Proposed Revision of S.A.E. Standard)

The Electrical Equipment Division recommends that the present S.A.E. Standard for Generator Flange Mounting, page B17, S.A.E. Handbook, be revised by changing dimension *L*, the length of the shaft-end from the hub to the center of the cotter-pin hole, from 1-25/32 to 1-13/16 in., and by changing dimension *M*, the overall length of the shaft-end, from 1-15/16 to 2-1/32 in. These changes will make the length of the threaded portion of the shaft-end practically the same for both the No. 1 and No. 2 flanges and permit using the same armature shaft-end in either size of generator. The changes also allow the use of a washer between the castle-nut and the face of the gear or sprocket.

Starting-Motor Flange Mountings

(Proposed Revision of S.A.E. Standard)

The Electrical Equipment Division recommends that the present S.A.E. Standard for Starting-Motor Flange Mountings, page B19, S.A.E. Handbook, be revised to specify 7/16-in. drilled holes for the holding bolts instead of 13/32-in. diameter holes which will permit using a more common drill size and give a 1/16 instead of 1/32-in. clearance for the bolts. The change will also facilitate assembling of the starting motor on the engine, which is definitely located by the pilot on the starting-motor flange.

Flexible Steel Conduit

(Proposed Revision of Recommended S.A.E. Practice)

The Electrical Equipment Division recommends that the present S.A.E. Recommended Practice for Flexible Steel Conduit, page C52, S.A.E. Handbook, be revised to conform to the accompanying specification.

The Division's recommendation resulted from criticisms in reference to the present standard adopted by the Society in 1916. It was desired by the Division to base the revised standard on the standard for Insulated Cable that was adopted last July. A Subdivision was appointed which represented the principal conduit manufacturers and a tentative recommendation prepared, this being submitted for consideration at the October meeting of the Electrical Equipment Division. The report was circularized among conduit manufacturers prior to the meeting and is now submitted as the recommendation of the Electrical Equipment Division.

FLEXIBLE STEEL CONDUIT

General Information Flexible steel conduit is recommended for use as a mechanical protection to insulated electric wires, that otherwise would be exposed to injury and shall be of the square-locked type, made by coiling a formed metallic strip.

Conduit may be made of zinc-coated steel or of brass. When made of brass, the dimensions shall be the same as those of steel conduit.

Flexible metallic conduit may be of either the "packed" or "unpacked" type. Packed conduit may have either asbestos packing or cotton packing. Asbestos packing is preferable to cotton when the conduit is exposed to high temperatures.

Flexible metallic conduit shall be designated by nominal inside-diameter and specified thus: "⅜-in. inside diameter, asbestos packed, galvanized steel conduit", "½-in. inside diameter, unpacked, galvanized steel conduit".

Because of the general construction and flexibility of flexible conduit, there is a considerable difference in a given piece between the compressed or fully extended lengths. All measurements for length shall be based on the mean or average of the compressed and extended lengths.

Sizes and Dimensions—Table 4 of sizes, weights and strengths relates to packed and unpacked conduit.

TABLE 4—FLEXIBLE STEEL CONDUIT DIMENSIONS

Nominal Inside Diameter, in.	Actual Inside Diameter, in.[1] Min.	Actual Inside Diameter, in.[1] Max.	Outside Diameter, in., Max.	Thickness of Strip, in., Min.	Approximate Net Weight per 100 Ft., lb.	Tension, lb., Min.	Radius for Bending, in., Min.
3/16	0.188	0.200	0.28	0.010	6.0	40	3/4
1/4	0.250	0.265	0.35	0.010	8.0	60	7/8
5/16	0.313	0.330	0.42	0.012	10.0	70	1
3/8	0.375	0.395	0.48	0.012	11.5	80	1 1/4
7/16	0.438	0.460	0.55	0.012	13.0	85	1 3/8
1/2	0.500	0.525	0.62	0.014	16.0	90	1 1/2
5/8	0.625	0.656	0.75	0.014	20.0	100	2
3/4	0.750	0.790	0.92	0.016	25.0	120	2 1/4
7/8	0.875	0.920	1.03	0.016	33.0	125	2 5/8
1	1.000	1.050	1.16	0.016	40.0	125	3
1 1/4	1.250	1.313	1.42	0.018	50.0	125	3 1/2

[1] The limits specified in the table are those within which any make of conduit should be maintained and do not necessarily apply as the limits for any one piece of conduit.

Installation—To protect the electric wires from abrasion, and to prevent the conduit from unwinding, all exposed free ends, when installed, should be bushed with suitable ferrules soldered to the conduit. Where taps or joints are made, suitable junction-boxes shall be used, and also the ends of the conduit entering these boxes shall be carefully bushed with ferrules.

Specifications for Insuring Quality—To insure a product that will be suitable for the conditions ordinarily met in automobile wiring, flexible metallic conduit should conform to the following specifications:

(1) The conduit shall be such that a sample 3 ft. long will not open at any point when subjected for 1 min. to a tension test corresponding to the values given in Table 4

(2) The conduit must be such that it will not open when bent in a curve, the inner radius of which corresponds to the values given in Table 4

(3) The interior of the conduit shall be free from burrs or sharp edges that might cause abrasion of the insulation on the wire, and from obstructions that might interfere with the easy introduction of the maximum-size wire for which the conduit is normally suitable

Tests for Galvanizing—The copper-sulphate method is recommended for testing the galvanizing of flexible conduit. This cannot be considered as an exact test, but it does not require a chemist. With experience, anyone can determine quickly by comparison the amount of zinc coating.

The test solution is to be prepared by boiling pure water with sufficient crystals of chemically pure copper sulphate to give a saturated solution with an excess of copper sulphate when cool. The solution shall be neutralized by the addition of oxide of copper, then filtered and diluted to a specific gravity of 1.186 at 65 deg. fahr. A saturated solution requires about 27 parts of copper sulphate to 73 parts of water, by weight.

To guard against changes in specific gravity or saturation, the solution should not be kept in a room whose temperature falls much below 65 deg. fahr.

Method of Making Galvanizing Test—The solution shall be poured into a No. 1 tall glass beaker of about 2-in. diameter; about 100 c.c. shall be used for test of ¾-in. and smaller conduits, and about 125 c.c. for larger sizes. The same supply of solution shall be used for successive dips of any one sample, but a fresh supply shall be used for each new sample, and the used solution shall not be returned to the supply bottle.

The solution in the beaker shall be brought to a temperature of approximately 65 deg. fahr. before the test is made by placing the beaker in a larger vessel containing water at the proper temperature and stirring with a glass thermometer.

Pieces of conduit about 6 in. long shall be used for the test, with the ends cut off approximately square, cooled before the test if heated by sawing. Each sample shall be washed in running water, dipped up and down in a vessel containing either carbon tetrachloride or ether and allowed to dry before being placed in the test beaker.

The sample thus prepared shall be stood on end in the copper-sulphate solution for 1 min., without moving or stirring the solution. At the end of 1 min. the sample is to be removed, rinsed in running water and wiped lightly, inside and outside, with white cheesecloth until dry. Violent rubbing and contact with the hand or any other object are to be avoided.

Interpretation of Test—The zinc coating of the sample is dissolved by the solution and a coating of copper deposited in its place. As long as zinc remains, the copper can be removed easily by washing and wiping,

but when the zinc has been entirely dissolved at any point the copper deposited at that point will not wash or wipe off. The number of dips required to cause a fixed copper deposit is, therefore, in some degree a measure of the thickness of the zinc coating.

A sample of flexible conduit shall pass this test if it does not have any of its fixed immersed surface covered with a fixed copper deposit after 1 min. of immersion, or more than 25 per cent of its immersed surface covered with a fixed copper deposit after a second immersion for 1 min. Several samples should be tested and a comparison noted.

Each sample shall be subjected to at least one additional dip, and the dips are generally continued until the entire immersed surface is coated with a fixed copper deposit.

Non-Metallic Conduit

(Proposed S.A.E. Recommended Practice)

The Electrical Equipment Division recommends for adoption as S.A.E. Recommended Practice the accompanying specification for non-metallic conduit for electrical wiring. This specification was formulated by the Subdivision on Flexible Conduit, together with the specification for flexible steel conduit, to fill the demand created by the extensive use of non-metallic conduit or "loom" in wiring cars for electrical apparatus. The two specifications were developed together and afford a definite basis for the purchasing and testing of these materials.

TABLE 5—NON-METALLIC FLEXIBLE CONDUIT DIMENSIONS

Nominal Inside Diameter, in.	Actual Inside Diameter,[2] in.		Outside Diameter, in., Max.	Approx. Weight, lb. per 100 Ft., lb.	Minimum Radius for Bending, in.	
	Min.	Max.			At 50 deg. Fahr.	At 70 deg. Fahr.
3/16	0.188	0.200	0.400	3.9	6	1/2
7/32	0.219	0.293	0.480	4.2	6	1/2
1/4	0.313	0.335	0.530	4.5	6	1/2
3/8	0.375	0.450	0.725	6.1	6	1/2
1/2	0.500	0.565	0.875	8.3	6	1/2
5/8	0.625	0.736	0.975	10.2	..	..
3/4	0.750	0.820	1.125	11.5	..	..
1	1.000	1.050	1.313	16.0	..	..
1 1/4	1.250	1.325	1.675	20.5	..	..

[2]The limits specified in this table are those within which any make of conduit should be maintained and do not necessarily apply to any one piece of conduit.

NON-METALLIC FLEXIBLE CONDUIT

General Information—Non-metallic flexible conduit is recommended for use as a mechanical protection to insulated wire that otherwise would be exposed to injury. Conduit shall be designated by the nominal inside-diameter.

Sizes and Dimensions—The sizes are listed in Table 5. The radius at which conduit can be bent without rupture depends on the temperature as well as on the wires enclosed in it at the time the bend test is made. Because of this the minimum radius for bending is given for conduit enclosing the largest wire for which it is suitable, and at two different temperatures. Conduit of greater than ½-in. nominal inside-diameter is ordinarily used for enclosing groups of wires that may vary in their makeup. It is, therefore, difficult to give definite radii for these sizes.

Installation—Conduit is treated with a moisture-repellant compound on the outside, but is not treated to withstand water on the inside. Therefore, when installed, the ends should be carefully sealed with friction tape, or other effective means to prevent the entrance of moisture.

As a further protection, a hole approximately ⅛ in. diameter should be burned with a hot iron in the bottom of the conduit at each pocket or low point, so that any moisture that may collect in the conduit will drain out.

Specifications for Insuring Quality—To insure a product that will be suitable for the conditions ordinarily met in automobile wiring, the conduit should conform to the following specifications. As a conduit is somewhat subject to aging, the tests should be made within 1 month of the date of manufacture.

(1) The design and construction of the conduit shall be such as to afford adequate mechanical protection to the wire. Its dimensions shall conform to Table 5 and all materials used must be electrically non-conducting

(2) Conduit that is made with a double wall shall be constructed so that the inner wall will not be removable in lengths of more than 3 ft.

(3) The conduit shall be free from obstructions that might cause abrasion of the insulation on the wire or interfere with the easy introduction of the maximum-size wire for which the conduit is normally suitable

(4) All sizes of conduit shall be capable of withstanding a tension test of 200 lb. for 5 min. without breaking or opening at any point. The elasticity of the conduit shall be such that 5 min. after the test-force has been removed, the elongation, measured between marks placed 20 in. apart on the sample before test, will not be more than 15 per cent

(5) Conduit in sizes up to and including ½-in. inside-diameter, when containing an insulated wire of the maximum diameter for which it is normally suitable, shall be capable of being bent without rupture to a radius of 6 in. when at a temperature of 50 deg. fahr., or to a radius of ½ in. when at a temperature of 70 deg. fahr.

(6) The conduit shall be capable of being flattened with a wooden mallet for a length of 6 in. in the center of a longer length, or by being trod on until the opposite walls are forced together, and of their being restored to roundness by working with the fingers so that a wire of maximum size for which it is normally suitable may be readily introduced. The compound must not crack open in this test

(7) The outer surface of the conduit shall be treated with a moisture-repellant compound. Test samples from 6 to 8 in. long, closed with corks, sealed by dipping in melted paraffin, immersed vertically in water at from 62 to 70 deg. fahr. for 24 hr. and then wiped dry with cloth or blotting paper, must not show an increase of more than 10 per cent in weight

(8) The conduit shall not convey fire, nor support combustion for more than 1 min. after five 15-sec. applications of a standard test-flame, with intervals of 15 sec. between applications. A standard test-flame is the blue flame, about 5 in. high, produced by a ½-in. Bunsen burner, fed with ordinary illuminating gas at normal pressure

(9) The compounds must not drip from the conduit when at a temperature not exceeding 160 deg. fahr.

ENGINE DIVISION REPORT

CARBURETER FLANGES

(Proposed Revision of S.A.E. Standard)

At the meeting of the Engine Division held last April a Subdivision was appointed to consider the consolidation [illegible] present carbureter sizes in answer to requests [illegible]d been received by the Division. The elimination [illegible]e or two sizes was considered but deemed unwise. [illegible]posal was then prepared by the Subdivision in [illegible]h the flange dimensions of the ½ and ⅝-in. nominal-size [illegible]arbureters and of the ¾ and ⅞-in. sizes were the same. This was circularized among the carbureter and engine manufacturers for approval or suggestions. The replies received indicated general approval.

It is therefore recommended by the Engine Division that the flange dimensions for the ½-in. nominal-size carbureter shall conform with the dimensions shown in the present standard, page A8, S.A.E. HANDBOOK, for the ⅝-in. size, and that the flange dimensions for the ¾-in. size shall be the same as for the ⅞-in. nominal size. All of the nominal carbureter openings in the present standard are to be retained.

ENGINE NUMBERS

(Proposed Revision of S.A.E. Standard)

Three years ago a special committee of the Society was appointed to confer with a committee of the National Automobile Chamber of Commerce and representatives of the Underwriters Laboratories with a view to recommending some suitable means for locking automobiles so as to minimize theft. This committee was eventually continued to serve in a technical advisory capacity with the Insurance Committee of the National Automobile Chamber of Commerce and the Underwriters Laboratories with regard to a new method proposed by the latter of establishing insurance ratings for different makes of automobile, based on the hazards involved in various types of mechanical construction and the materials used. In the deliberations at joint meetings of the committees it was stated by the representatives of the Underwriters Laboratories that wherever S.A.E. Standards were considered suitable for the purpose, they would be included in the insurance-hazard schedule that was under study. Discussion of theft hazards led to consideration of methods of marking or numbering engines, frames and other major parts of automobiles so that the numbers could not be readily effaced or changed, but be readily visible for the purpose of inspection. The representatives of the Underwriters Laboratories expressed the view that the present S.A.E. Standard method of numbering does not give the desired protection, and it was requested that the possibilities of devising a system of numbering that would be more effective be studied. The subject was taken up in the Engine and the Frames Divisions and a general questionnaire sent to engine and automobile manufacturers, representatives of the insurance companies and a few metallurgists to secure comment on the numbering systems that had been suggested and to elicit further ideas. The majority of the replies indicated the use of and preference for plain figures about ¼ in. high deeply stamped into a pad or plain surface cast on the engine. Several suggestions were submitted, such as inserting an expanded disc in a counterbored hole in the crankcase, casting a special alloy in the engine crankcase on which the engine number might be stamped, casting numbers of an opaque material in the cylinder block in such a way that an X-ray photograph would show the numbers, using raised numbers, casting a small thin fin on which the numbers could be stamped on the crankcase so that the fin could be broken off by the dealer and held by the purchaser, and casting on a small thin brass plate with edges crimped down ⅛ in. and knurled so as to anchor the edges securely in the crankcase. The suggested methods were considered by the Engine Division and the following revision of the present S.A.E. Standard, page A13, S.A.E. HANDBOOK, was finally recommended. The method submitted is considered the simplest and most effective practical system for numbering engines that has been devised for protection against theft.

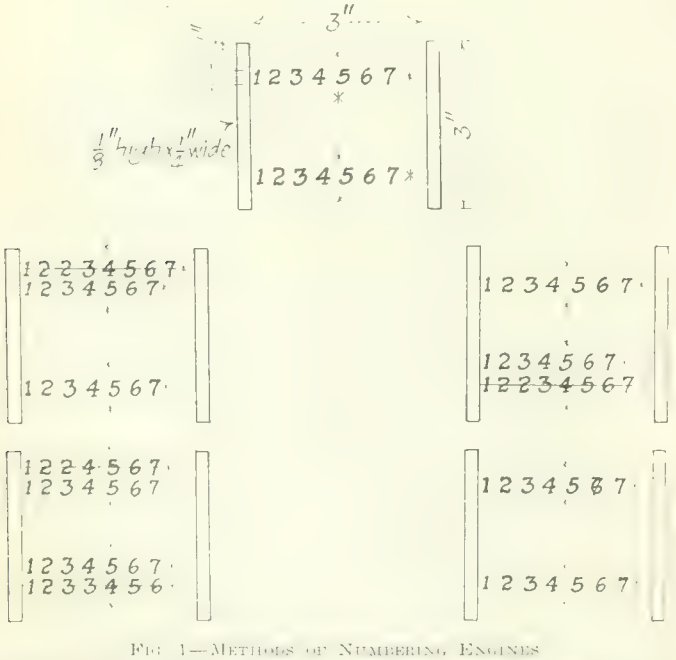


FIG. 1—METHODS OF NUMBERING ENGINES

The Arrangement in the Single View at the Top Is Correct and the Numbering in the Upper Pair of Drawings Is Acceptable, Only One Number Having Been Corrected in Each Case. The Lower Pair of Drawings Show Two Cases That Are Not Permissible in the Drawing at the Left Both Numbers Have Been Corrected or Changed, While in the Other Drawing a Single Digit Has Been Corrected by Stamping a Second Digit over the Original One

> The engine serial or identification number shall be placed near the top of the right-hand side of the crankcase proper in a position in which it can be read easily. It shall be between two vertical ribs or beads ¼ in. wide, ⅛ in. high, 3 in. long and 3 in. apart as shown in the single drawing at the top of Fig. 1. The surface of the casting between the ribs shall be left rough as cast and unpainted on the finished engine. The numbers shall be evenly stamped in the casting 1/32 in. deep and shall be ¼ in. high and of script form. The first digit shall be stamped close to the left-hand rib and the last digit shall be followed by a large star or other character to prevent adding digits. A star or other character also shall be stamped immediately above and below each number to prevent adding another number. The numbers shall be stamped twice on each casting, as illustrated, to permit correcting any errors made in stamping either number. No other number or character shall be placed within the space provided.
>
> If an error is made in stamping one number, it may be crossed out and the correct number stamped in immediately above or below as shown in the upper pair of drawings in Fig. 1. In no case shall both numbers be crossed out as shown in the lower left corner and new ones stamped, and more than three numbers must never appear, one wrong number crossed out and two correct numbers.

By this method, in case an error is made in stamping

either number, an additional number would be stamped directly under or above the number, the number stamped in error being cancelled by stamping a horizontal line through it. In this way two correct unmutilated numbers would appear on each engine. In case errors were made in stamping both the original numbers, the casting would be scrapped, as the system requires that at least one of the two original numbers be not mutilated in any way. The proposed method of numbering engines does not require additional skilled employes or tool equipment, but its adoption should be preceded by an educational campaign in the shops to impress the men who number the engines with the necessity for care and accuracy in doing the work. It has been suggested that a fine or other suitable penalty be imposed for carelessness or the spoiling of a certain percentage of castings by wrong numbering, but it is believed that by properly instructing the employes practically no errors would be made which would necessitate scrapping castings.

The other important reason for using a method of numbering engines that will make mutilation or changing of the numbers evident, is to obtain the 7½-per cent reduction in theft-insurance premiums that the underwriters state will be allowed. The arrangement under which the premium reductions may be had are

(1) If only the engine number or car-frame number conforms with the underwriters' requirements, a reduction of 7½ per cent in the theft-insurance premium will be allowed
(2) If both the engine and frame numbers conform with such requirements, a reduction of 20 per cent in the premium will be allowed

Work is under way in the Frames and Passenger Car Divisions with the object of formulating another method of numbering car frames than the present standard, page K41, S.A.E. HANDBOOK, to make available the 20-per cent reduction in insurance premiums as soon as possible, but the numbering of frames involves difficulties not encountered in numbering engines.

FAN BELTS AND PULLEYS

(Proposed Revision of S.A.E. Recommended Practice)

The present standard for fan belts and pulleys, page A14, S.A.E. HANDBOOK, which was adopted by the Society in 1915, includes only flat belt and pulley widths. The development of better fan and fan-drive mechanisms required for the more efficiently cooled modern engines has led the Engine Division to revise and extend the standard. A Subdivision was appointed to prepare the proposed specification which includes flat and V-belts and pulleys and fan-pulley spindles for solid and adjustable fan-brackets. Criticisms of the Subdivision's proposal were considered by the Engine Division which now presents the recommendation embodied in Figs. 2 to 6 and Tables 6 to 12 inclusive.

TABLE 6—FLAT FAN-BELT AND PULLEY DIMENSIONS

Belt Width,[3] in.	Pulley Width,[4] in.	Maximum Fan Diameter, in.	Maximum Projected Blade Width, in.
1	1⅛	Up to 14	1⅝ Inclusive
1¼	1⅜	15 to 18	1⅞ Inclusive
1½	1¾	19 to 20	2 Inclusive
2	2¼	20 to 22	2¼ Inclusive
2½	2¾	21 to 24	2½ Inclusive
3	3¼	25 to 26	2½ Inclusive

[3] The widths given are subject to a variation of +1/32 in.
[4] The widths given are subject to a variation of ±0.01 in.

TABLE 7—V-FAN BELT AND PULLEY DIMENSIONS

Width of V-Belt at Top, in.	Minimum Depth of Groove Below Bottom of Belt, in.	Maximum Fan Diameter, in.	Maximum Projected Blade Width, in.
⅝	⅛	Up to 14	1⅝ Inclusive
⅝	⅛	15 to 18	1⅞ Inclusive
¾	3/16	19 to 20	2¼ Inclusive
1	3/16	21 to 22	2½ Inclusive
1¼	5/16	23 to 26	2½ Inclusive

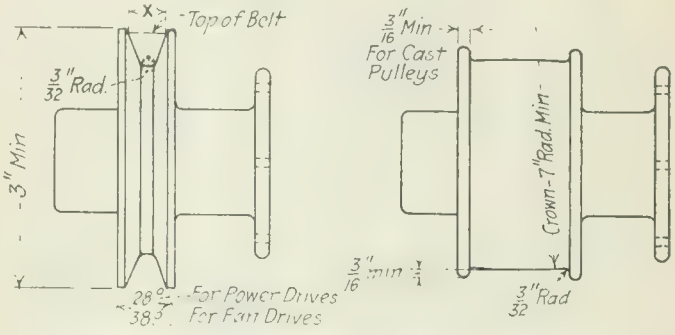


FIG. 2—TWO TYPES OF FAN PULLEYS
That Illustrated at the Left Is for a V-Belt and That at the Right for the Flat Type of Belt

TABLE 8—FAN-PULLEY DIMENSIONS

Ratio of Fan Driving Pulley to Engine Speed	Minimum Fan-Driving Pulley Diameter, in.	Minimum Fan-Driven Pulley Diameter, in.[5]
½	7½	3
1	5	3
1½	3	3

[5] Diameter to increase by ¼-in. increments.

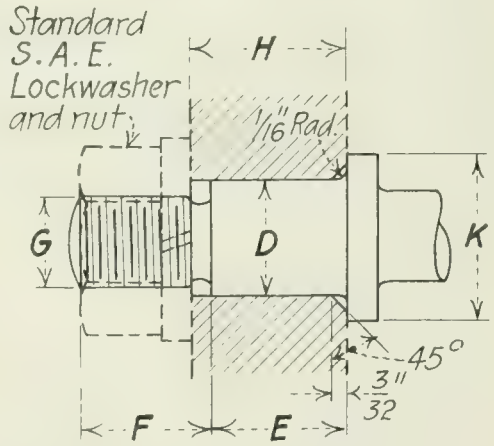


FIG. 3—FAN PULLEY SPINDLE FOR USE WITH SOLID BRACKETS

TABLE 9—DIMENSIONS OF FAN-PULLEY SPINDLE FOR SOLID FAN-BRACKETS

Width of Belt, in.	*D*	*E*	*F*	*G*	*H*	*K*
1-1¼	0.748	⅞	⅞	⅝-18	1	1
	0.746					
1½	0.873					
	0.871	1	⅞	⅝-18	1⅛	1⅛
2	0.998					
	0.996	1⅜	15/16	¾-16	1⅝	1¼
2½-3	1.248					
	1.246	1 9/16	1 5/16	1-14	2	1½

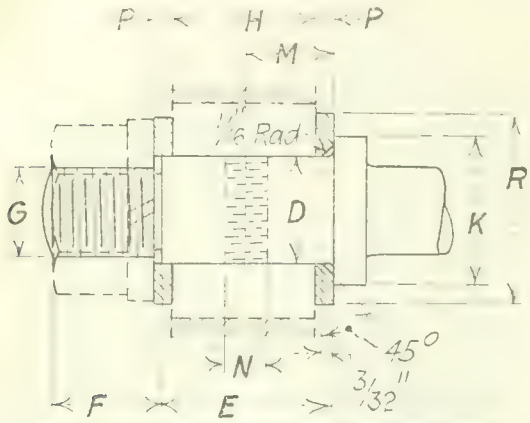


FIG. 4—FAN-PULLEY SPINDLES FOR USE WITH SLOTTED BRACKETS

TABLE 10—DIMENSIONS OF FAN-PULLEY SPINDLES FOR SLOTTED FAN-BRACKETS

Width of Belt, in.	1-1¼	1½-2	2½-3
D	0.748	0.998	1.248
	0.746	0.996	1.246
E	1 3/16	1 9/16	1 7/8
F	13/16	15/16	1¼
G	⅝-18	¾-16	1-14
H	1	1⅛	1½
K	1	1¼	1½
M	⅝	13/16	1
N	5/16-18	½-13	½-13
P	⅛	¼	¼
R	1⅜	1¾	2

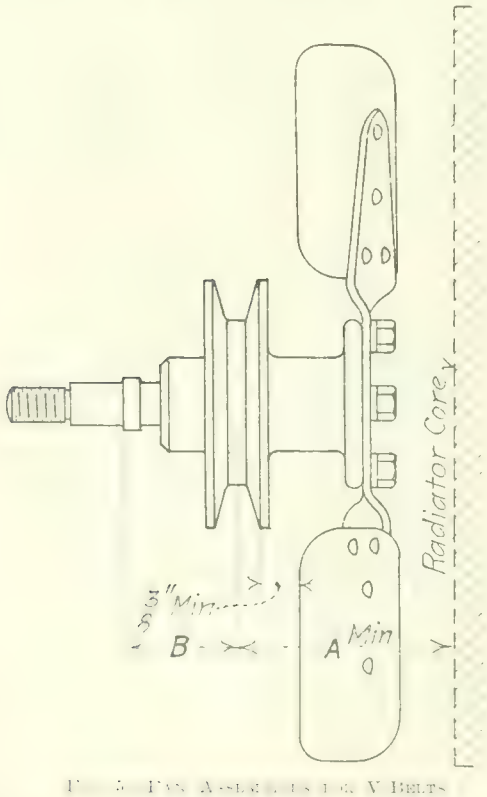


FIG. 5—FAN ASSEMBLIES FOR V-BELTS

TABLE 11—FAN-ASSEMBLY DIMENSIONS FOR V-BELTS

Belt Widths, in.	*A*	*B*
⅝	3½	1½
¾	3½	1¾
1	4	2⅛
1¼	4	2⅛

The different characteristics of the several types of V-belt have been considered and as many data included in the recommendation as is considered feasible. The details of the pulleys, spindles, fan blades and general location of the assemblies with respect to the radiator core have been checked against present practice and it is believed that general adoption of the recommendation will provide for much more efficient fan installations at reduced cost to the engine builders.

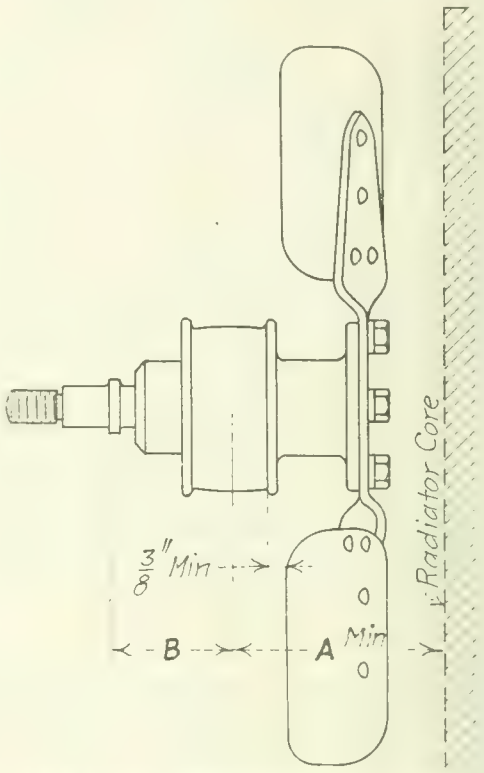


FIG. 6—FAN ASSEMBLIES FOR FLAT BELTS

TABLE 12—FAN-ASSEMBLY DIMENSIONS FOR FLAT BELTS

Belt Widths, in.	*A*	*B*
1	3¾	1¾
1¼	3¾	1¾
1½	3¾	1¾
2	4¼	2
2½	4¾	2½
3	4¾	2½

Angle of Groove—The included angle of the sides of rubber V-belts shall be 32 deg. for power-drive belts, and 42 deg. for fan-drive belts. This allows for the bulging of the inside of the belts when laid around pulleys.

Width of Groove—The width of the pulley groove measured at the outside diameter of the pulley shall clear the maximum width of the belt. For link belts, the next larger size pulley should be used.

ENGINE TESTING FORMS

(Proposed Revision of S.A.E. Standard)

For some time the Engine Division has been studying the possibility of extending the present S.A.E. Standard for Engine Testing Forms, page A16, S.A.E. HANDBOOK, to provide for the recording of data on testing internal-combustion engines of other than the automobile type, such as heavy stationary and farm lighting-plant engines, but it has been found impracticable to do so. The Subdivision submitted a tentative recommendation to the

Engine Division, however, proposing the adoption of the following changes in the present testing forms which have been approved by the Division.

Specification Sheet B

Under Item No. 6, Cooling System, provide for recording the fan diameter, projected width of fan-blades and the ratio of fan speed to engine speed.

Under Item No. 32, Lubricating System, Type and Description, provide for recording the Saybolt viscosity at Cold Test, 150 deg. fahr. and 350 deg. fahr.

Add a section entitled Accessories containing Item 33, Accessories Attached during Test, under which are to be listed the accessories attached to the engine during the test and conditions under which they operated.

Log Sheet C

Add a note to the effect that it is recommended that results be corrected to a temperature of 60 deg. fahr. and 29.92 in. of mercury barometric pressure by using the formula

$$\text{B. Hp}_c = [\text{B. Hp}_o \times P_s] \div [P_o \times (T_o/T_s)]$$

where

B. Hp_c = corrected brake horsepower
B. Hp_o = observed brake horsepower
P_o = observed barometric pressure in inches of mercury
P_s = standard barometric pressure in inches of mercury
T_o = observed absolute temperature in degrees fahrenheit
T_s = standard absolute temperature in degrees fahrenheit

Curve Sheet D

Change the ordinates for the fuel consumption from "0.5 to 2.5" to "0.5 to 1.5" lb. per b.hp-hr. so that four ordinate lines will represent 0.1 lb. per b.hp-hr.

Insert the intermediate values for the brake horsepower ordinates.

MUFFLERS

(Proposed S.A.E. Recommended Practice)

Last year the Engine Division prepared a recommendation principally with regard to the mounting of mufflers, but it was felt that this subject should be thoroughly investigated before a standard, if recommended at all, should be adopted. A Subdivision was appointed and a mass of data on existing practice obtained with the intention of, if possible, arranging a series of muffler sizes in accord with a definite range of engine displacements. These data showed a total lack of uniformity of muffler capacity with regard to piston displacement and it was therefore decided to consider the subject from the point of view of muffler sizes in general use. The Subdivision prepared a report that was submitted to engine manufacturers and their replies were considered by the Engine Division. After careful study of the report and the generally favorable comments with regard to its adoption, the Engine Division has approved the accompanying proposal for adoption as S.A.E. Recommended Practice. The proposal is limited to nine sizes given in Table 13 that circularization indicates are most popular and are considered adequate for all general applications. The exhaust-tubing and tail-pipe sizes proposed were selected as being suitable for the usual range of engine sizes, and are identical for all mufflers of the same diameter. As many mufflers are built up of sections, they can be obtained in a variety of lengths, but with standard heads. The lengths proposed are those in most general use and permit the use of a width of stock for the one-piece type that is readily procurable from the steel mills.

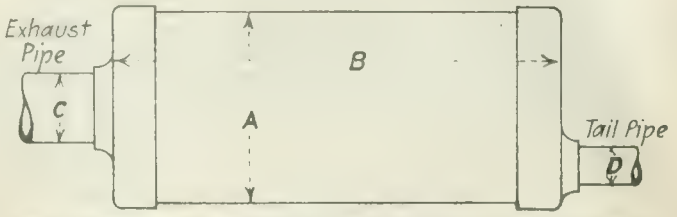


FIG. 7—PROPOSED RECOMMENDED PRACTICE FOR ENGINE MUFFLERS

TABLE 13—RECOMMENDED STANDARD SERIES OF MUFFLERS

	A	B	C	D
No.	Diameter, in.	Length, in.	Muffler Volume, cu. in.	Exhaust-Pipe Tube-Diameter, in.	Tail-Pipe Tube-Diameter, in.
1	5	20	390	2	1½
2	5	24	470	2	1½
3	5	28	550	2	1½
4	6	20	565	2½	1¾
5	6	24	680	2½	1¾
6	6	28	790	2½	1¾
7	7	20	770	3	2
8	7	24	925	3	2
9	7	28	1,008	3	2

It is recommended that the length of the exhaust-pipe tubing shall not be less than 5 ft. from the exhaust-manifold to the muffler.

It is the intention of the Division to standardize muffler mountings after the present proposal has become effective, provided such standardization seems desirable.

FRAMES DIVISION REPORT

RUNNING-BOARD BRACKETS

(Proposed S.A.E. Recommended Practice)

The Frames Division recommends for adoption as S.A.E. Recommended Practice the passenger-car running-board brackets shown in Fig. 8. Running-board or step brackets in present-day use are in general similar, but the elimination by standardization of variations such as those in the number, size and location of the rivet-holes and the radius of the curve will make it possible to obtain interchangeable brackets more easily and permit savings

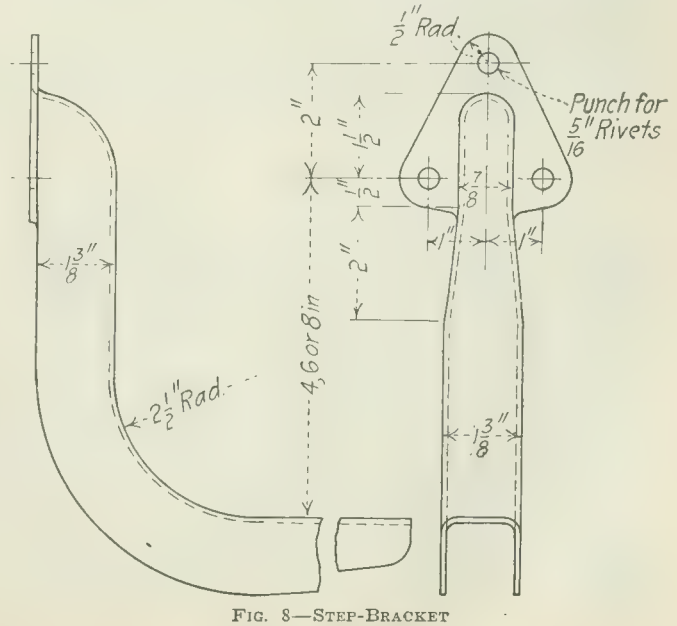


FIG. 8—STEP-BRACKET

in tools and in the time required for punching or drilling the frames. Three heights of bracket are recommended, which, it is believed, will suit any height of running-board by proper selection. If further variation is necessary, it can be obtained by shifting slightly the position of the rivet-holes in the frame. The width of the brackets can be changed readily to suit various widths of running-board.

IRON AND STEEL DIVISION REPORT

Iron and Steel Specifications

(Proposed Revision of S. A. E. Standards)

Realizing the need of bringing the S.A.E. Steel specifications and the notes that accompany them uptodate, so as to reflect current metallurgical practice; also the need for physical-property charts covering all of the S.A.E. Steels, the Iron and Steel Division undertook about 2 years ago a thorough revision of the S.A.E. Steel Specifications and the notes referring to them.

Owing to the advantage they had obtained in the past from the work of the Society by the standardization of steel specifications, the automobile and parts manufacturers and the steel producers all extended their hearty and active cooperation in this work. In addition to the representatives of these interests, the personnel of the Division was supplemented by representatives from the Ordnance Department and the engineering division of the Air Service; also by representatives of corresponding committees of the American Gear Manufacturers' Association and of the American Society for Testing Materials.

The specifications covering the chemical compositions were all reconsidered and certain little-used compositions deleted. Minor revisions were made in a number of other compositions and additions to the list of standard steels were made in response to requests from other engineering organizations which had adopted S.A.E. Steels for their needs, particularly the metallurgical committee of the American Gear Manufacturers' Association.

The Division also undertook to collect and tabulate data obtained from users of S.A.E. Steels on the physical properties of the various compositions after heat-treatment in accordance with the recommendations of the Society. The statistical data thus obtained were transferred to graphs and further checked by actual tests in the laboratories of some of the Division members, with the result that the Division is now able to submit charts of physical properties for the 3200, 3300 and 3400 series of S.A.E. Steels. Work on the 6100 series is not complete.

Conservative Values Indicated

In presenting these charts the Division desires to emphasize that the properties shown indicate conservative values that should be obtained with proper heat-treatment of material within the ranges of composition specified *on sections from* ½ *in. to* 1½ *in. diameter or thickness* and that *for sections over* 1½ *in. diameter or thickness these charts do not apply.*

The Division is working on the preparation of additional charts for sections greater than 1½ in. and, while substantial progress has been made, it is not prepared to submit a definite report at this time.

After considering carefully the extent of the revision of the notes pertaining to S.A.E. Steels, the Division decided to recommend specific temperature-ranges for specific compositions, instead of following the former method of general treatments applying to several steels, thereby permitting of the application of narrower temperature-ranges in each heat-treatment.

In order that there might be no confusion in connection with such shop drawings as are in circulation and which carry the former heat-treatment symbols, it was decided to adopt Roman numerals for the revised heat-treatments, in lieu of the alphabetical symbols that have heretofore been used. These Roman numerals are placed after the steel specification number, thereby indicating at a glance the specific composition of steel and its heat-treatment.

Specific Heat-Treatments

Further study revealed that eight types of heat-treatment will cover general commercial applications. Five of these treatments apply to case-hardening practice and the other three are so-called toughening or hardening treatments. All the treatments recommended are intended to reflect the best metallurgical practice. It is appreciated, however, that there are instances where treatments that are satisfactory have been developed by some manufacturers which will vary from those recommended by the Division. It has been the aim of the Division to recommend only such treatments as will develop safely the characteristic physical properties of each steel. It is possible that in certain instances a manufacturer will be confronted with particular conditions wherein the recommended treatment for a given steel will not apply in every detail. In such instances, the specific treatment must be determined by careful study and balancing of local conditions.

The types of heat-treatments recommended are as follows:

Heat-Treatment I—Carburize, quench from box and draw

Heat-Treatment II—Carburize, quench from box; reheat once to refine the case, quench and draw

Heat-Treatment III—Carburize, quench from box; reheat twice and quench twice, to refine the core and harden the case respectively, and draw

Heat-Treatment IV—Carburize, cool in box; reheat once to refine the case, quench and draw

Heat-Treatment V—Carburize, cool in box; reheat and quench twice, to refine the core and harden the case respectively, and draw

Heat-Treatment VI—Heat, quench and draw. A toughening or hardening treatment for parts machined from bar stock that are to be heat-treated either before or after machining

Heat-Treatment VII—Normalize, reheat, quench and draw. A toughening or hardening treatment for forged parts, usually applied before machining

Heat-Treatment VIII—Normalize, anneal, machine, reheat, quench and draw. A treatment for parts made from steels requiring a normalizing and annealing treatment prior to machining and final treatment. Particularly essential for forged parts of the higher alloy compositions. This treatment is particularly adapted to oil-hardening gear steel

The Iron and Steel Division has continued the use of the S.A.E. system of code numbers for identifying the grades and types of steel. Although this system may not describe perfectly the detailed composition of each steel, it has been adopted generally throughout the steel trade; in addition, it has been extended by individual firms to designate many grades of steel not actually included in the S.A.E. specifications.

While it is realized by the Division that the present system using four or five digits does not indicate precisely all the alloying elements and their percentages, it

is a system that has served well in the past and the limit of its applications has not yet been reached. At various times other systems of symbols have been suggested, all of them based on the present successful S.A.E. system, in which complicating symbols, such as letters and various combinations of numbers, have been employed. Entirely aside from the fact that the present S.A.E. numbers are established and identified on hundreds of thousands of blueprints and specification sheets, the proposed changes have not been able to withstand the light of extensive criticism, due to the fact that their disadvantages have outweighed their apparent advantages.

There is a Subdivision of the Iron and Steel Division whose duty it is to make an extensive study of this phase of the work, and it has given and it will give careful consideration to any suggestions that have been or may be offered looking toward the improvement and extension of the present code.

Application of Data

The complete data regarding each grade of steel, such as the code number, the composition, certain notes descriptive of the steel, and the heat-treatments that will apply for such composition and charts showing the physical properties that may be developed by the recommended heat-treatments, will probably appear on the same page or on opposing pages of the final report and of the data sheets. The engineer will then have assembled before him complete data for each particular grade of steel. He can compare them easily and choose the one that will apply best to his particular purpose. For example, if it is desired to use a steel for certain structural parts that require a yield-point of 90,000 to 100,000 lb. per sq. in., and an elongation in 2 in. of about 18 per cent, it will be found upon reference to the various charts that there are several types or compositions that will provide the desired physical properties. With this array of available material before him, the engineer, production manager or metallurgist is in a position to make a choice, after taking into consideration such important factors as ease of machinability, resistance to shock and fatigue, penetration of hardening effect, ease of heat-treating, availability and price.

Economic Advantages

The standardization work of the Iron and Steel Division has cultivated widespread use of the S.A.E. Steel Specifications as a common language between the user and the producer of low and medium carbon ranges of plain-carbon and alloy-steels suitable for a great variety of applications; and the economic benefits resulting from the use of the S.A.E. Steels have been so evident and so clearly defined in the manufacturing world that they have been adopted generally in industries other than those in the automotive field. This very extensive use of S.A.E. Steels is reflected in the great number of inquiries received by the Society for the reports of the Division. These requests come from all branches of the metal trades in nearly every State in the Union, as well as from foreign countries. The demand from the small manufacturers for the reports of the Division is particularly noticeable and the form of their requests indicates that they find the specifications for S.A.E. Steels of great value. As stated by K. W. Zimmerschied, a former chairman of the Iron and Steel Division, "The specifications are intended to provide a good commercial quality of steel, leaving the ultra refinements to those whose problems or conditions require such special treatment." The outstanding fact is that the use of heat-treated carbon and alloy-steels has contributed largely to the phenomenal success of the automotive industry, and the S.A.E. Steel Specifications have standardized them for consumers and producers alike.

Acknowledgment is made of the cooperation and valuable information furnished to the members of the Iron and Steel Division by the following non-members who, among others, have assisted materially in preparing the revised report and discussing the many phases of the work at the Division's meetings.

S. P. Rockwell	American Gear Manufacturers Association
John Miller	Pierce-Arrow Motor Car Co.
J. H. G. Williams	Billings & Spencer Co.
M. H. Schmid	United Alloy Steel Co.
M. P. Rumney	Detroit Steel Products Co.
E. J. Janitzky	Illinois Steel Co.
M. T. Lothrop	Timken Roller Bearing Co.
H. T. Chandler	C. Harold Wills Co.
V. A. Crosby	Recently with Packard Motor Car Co.
A. H. Miller	Midvale Steel & Ordnance Co.

Part I—Introduction

The steel compositions included in this report are considered adequate for practically all parts made of ferrous materials that are necessary for the production of automotive apparatus, and include grades that have been found commercially available and technically adequate for the service required of such parts. In cases where very special requirements or exceptional quality make it necessary, grades containing less phosphorus and sulphur and narrower ranges of carbon and manganese are available, but such steels should be obtained by special arrangement between the mill and the purchaser.

Specification Numbers

A numeral index system is used for the specifications contained in this report, which makes it possible to use specification numerals on shop drawings and blueprints that are partially descriptive of the quality of material covered by such numbers. The first figure indicates the class to which the steel belongs: thus "1—" indicates a carbon steel; "2—" a nickel steel and "3—" a nickel-chromium steel. In the case of the alloy steels, the second figure generally indicates the approximate percentage of the predominant alloying element. Usually the last two or three figures indicate the average carbon-content in "points," or hundredths of 1 per cent. Thus 2340 indicates a nickel steel of approximately 3 per cent nickel, 3.25 to 3.75, and 0.40 per cent carbon, 0.35 to 0.45; and 71360 indicates a tungsten steel of about 13 per cent tungsten, 12 to 15, and 0.60 per cent carbon, 0.50 to 0.70. The basic numerals for the various qualities of steels specified are

Carbon steels	1
Nickel steels	2
Nickel-chromium steels	3
Molybdenum steels	4[a]
Chromium steels	5
Chromium-vanadium steels	6
Tungsten steels	7
Silico-manganese steels	9

[a] This numeral has been agreed upon as the index to the Molybdenum group but no specific compositions have as yet been recommended by the Iron and Steel Division.

Regarding Specifications and Notes on Heat-Treatments and Physical Properties

The Notes on heat-treatments and physical properties are not to be considered in any way a part of the stand-

ard specifications for S.A.E. Steels. They are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

S.A.E. Steels should be purchased on the basis of requirements as to chemical composition, and the specifications provided herein should be used in the purchase of grades and types of steel covered by each. Requirements as to physical properties have been omitted for all steels except steel castings because the majority of steels for automotive purposes are either worked or given special heat-treatments by the purchaser.

Part II—Specifications for Automotive Steels

(Proposed Revision of S.A.E. Standard)

Manufacture

Process

The steel shall be made by the Bessemer, open-hearth, crucible, electric, or any other process approved by the purchaser.

Discard

A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

Chemical Properties

The steel shall conform to the specified requirements as to chemical composition.

Ladle Analysis

An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified. This analysis shall be made from drillings taken at least ¼ in. beneath the surface of a test ingot obtained during the pouring of the melt, and in as sound metal as possible. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified.

Check Analysis

Analyses may be made by the purchaser. The chemical composition thus determined shall conform to the requirements specified.

Drillings for analyses of bars, billets or other regular shapes shall be taken parallel to the axis, at any point midway between the center and the surface.

Drillings or cuttings for analyses of irregularly shaped pieces shall be taken from both the thickest and the thinnest sections. Surface drillings shall be discarded.

Wire, tubing, sheets, and rods less than 1¼ in. thick shall be sampled through or across the entire section.

Finish

Defects

The material shall be free from injurious defects and shall have a workmanlike finish.

Inspection and Rejection

Inspection

The inspector representing the purchaser shall have free entry at all times to all parts of the manufacturer's works that concern the manufacture of the material ordered while work on the contract of the purchaser is being performed. The manufacturer shall afford the inspector free of cost all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

The purchaser may make the tests to govern the acceptance or rejection of the material in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejections

Unless otherwise specified, any rejection based on tests made by the purchaser in its own laboratory shall be reported within 10 working days from the receipt of samples.

Material which shows injurious defects while being finished by the purchaser will be rejected, and the manufacturer shall be notified.

Rejection Tests

Samples tested by the purchaser in its own laboratory that represent rejected material, shall be preserved for one month from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

Part III—Chemical Composition[6]

(Proposed Revision of S.A.E. Standard)

Carbon Steels

S. A. E. No.	Carbon Range	Manganese Range	Phosphorus Max.	Sulphur Max.
1010	0.05–0.15	0.30–0.60	0.045	0.05
1015	*0.10–0.20*	*0.30–0.60*	*0.045*	*0.05*
1020	0.15–0.25	0.30–0.60	0.045	0.05
1025	0.20–0.30	0.50–0.80	0.045	0.05
1030	*0.25–0.35*	*0.50–0.80*	*0.045*	*0.05*
1035	0.30–0.40	0.50–0.80	0.045	0.05
1040	*0.35–0.45*	*0.50–0.80*	*0.045*	*0.05*
1045	0.40–0.50	0.50–0.80	0.045	0.05
1046	*0.40–0.50*	*0.30–0.50*	*0.045*	*0.05*
1050	*0.45–0.55*	*0.50–0.80*	*0.045*	*0.05*
1095	0.90–1.05	0.25–0.50	0.040	0.05

Screw Stocks

S. A. E. No.	Carbon Range	Manganese Range	Phosphorus Max.	Sulphur Range
1112	0.08–0.16	0.60–0.80	0.09–0.13	0.075–0.15
1120	0.15–0.25	0.60–0.90	.... 0.06	0.075–0.15

Steel Castings[7]

S. A. E. No.	Carbon	Phosphorus Max.	Sulphur Max.
1235	As required by physical properties	0.05	0.05

Nickel Steels

S. A. E. No.	Carbon Range	Manganese Range	Phosphorus Max.	Sulphur Max.	Nickel Range
2315	0.10–0.20	*0.30–0.60*	0.04	0.045	3.25–3.75
2320	0.15–0.25	0.50–0.80	0.04	0.045	3.25–3.75
2330	0.25–0.35	0.50–0.80	0.04	0.045	3.25–3.75
2335	0.30–0.40	0.50–0.80	0.04	0.045	3.25–3.75
2340	0.35–0.45	0.50–0.80	0.04	0.045	3.25–3.75
2345	0.40–0.50	0.50–0.80	0.04	0.045	3.25–3.75
2350	*0.45–0.55*	*0.50–0.80*	*0.04*	*0.045*	*3.25–3.75*
2512	max. 0.17	0.30–0.60	0.04	0.045	4.50–5.25

[6] The S.A.E. numbers in italics are proposed additions to the present list of standard compositions. Where a portion of the composition is set in italics a change from the present composition is indicated.

[7] See specification for steel castings.

NICKEL-CHROMIUM STEELS

S. A. E. No.	Carbon Range	Manganese Range	Phosphorus Max.	Sulphur Max.	Nickel Range	Chromium Range
3115	0.10–0.20	0.30–0.60	0.04	0.040	1.00–1.50	0.45–0.75
3120	0.15–0.25	0.30–0.60	0.04	0.045	1.00–1.50	0.45–0.75
3125	0.20–0.30	0.50–0.80	0.04	0.045	1.00–1.50	0.45–0.75
3130	0.25–0.35	0.50–0.80	0.04	0.045	1.00–1.50	0.45–0.75
3135	0.30–0.40	0.50–0.80	0.04	0.045	1.00–1.50	0.45–0.75
3140	0.35–0.45	0.50–0.80	0.04	0.045	1.00–1.50	0.45–0.75
3215	0.10–0.20	0.30–0.60	0.04	0.040	1.50–2.00	0.90–1.25
3220	0.15–0.25	0.30–0.60	0.04	0.040	1.50–2.00	0.90–1.25
3230	0.25–0.35	0.30–0.60	0.04	0.040	1.50–2.00	0.90–1.25
3240	0.35–0.45	0.30–0.60	0.04	0.040	1.50–2.00	0.90–1.25
3245	0.40–0.50	0.30–0.60	0.04	0.040	1.50–2.00	0.90–1.25
3250	0.45–0.55	0.30–0.60	0.04	0.040	1.50–2.00	0.90–1.25
3312	max. 0.15	0.30–0.60	0.04	0.040	3.25–3.75	1.25–1.75
3325	0.20–0.30	0.30–0.60	0.04	0.040	3.25–3.75	1.25–1.75
3335	0.30–0.40	0.30–0.60	0.04	0.040	3.25–3.75	1.25–1.75
3340	0.35–0.45	0.30–0.60	0.04	0.040	3.25–3.75	1.25–1.75
3415	0.10–0.20	0.45–0.75	0.04	0.040	2.75–3.25	0.60–0.95
3435	0.30–0.40	0.45–0.75	0.04	0.040	2.75–3.25	0.60–0.95
3450	0.45–0.55	0.45–0.75	0.04	0.040	2.75–3.25	0.60–0.95

CHROMIUM STEELS[1]

S. A. E. No.	Carbon Range	Manganese Range	Phosphorus Max.	Sulphur Max.	Chromium Range
5120	0.15–0.25	0.30–0.60	0.04	0.045	0.60–0.90
5140	0.35–0.45	0.50–0.80	0.04	0.045	0.80–1.10
5150	0.45–0.55	0.50–0.80	0.04	0.045	0.80–1.10
52100	0.95–1.10	0.20–0.50	0.03	0.030	1.20–1.50

CHROMIUM-VANADIUM STEELS

S. A. E. No.	Carbon Range	Manganese Range	Phosphorus Max.	Sulphur Max.	Chromium Range	Vanadium Min.	Vanadium Desired
6120	0.15–0.25	0.50–0.80	0.04	0.04	0.80–1.10	0.15	0.18
6125	0.20–0.30	0.50–0.80	0.04	0.04	0.80–1.10	0.15	0.18
6130	0.25–0.35	0.50–0.80	0.04	0.04	0.80–1.10	0.15	0.18
6135	0.30–0.40	0.50–0.80	0.04	0.04	0.80–1.10	0.15	0.18
6140	0.35–0.45	0.50–0.80	0.04	0.04	0.80–1.10	0.15	0.18
6145	0.40–0.50	0.50–0.80	0.04	0.04	0.80–1.10	0.15	0.18
6150	0.45–0.55	0.50–0.80	0.04	0.04	0.80–1.10	0.15	0.18
6195	0.90–1.05	0.20–0.45	0.03	0.03	0.80–1.10	0.15	0.18

TUNGSTEN STEELS

S. A. E. No.	Carbon Range	Manganese Max.	Phosphorus Max.	Sulphur Max.	Chromium Range	Tungsten Range
71360	0.50–0.70	0.30	0.035	0.035	3.00–4.00	12.00–15.00
71660	0.50–0.70	0.30	0.035	0.035	3.00–4.00	15.00–18.00
7260	0.50–0.70	0.30	0.035	0.035	0.50–1.00	1.50–2.00

SILICO-MANGANESE STEELS

S. A. E. No.	Carbon Range	Manganese Range	Phosphorus Max.	Sulphur Max.	Silicon Range
9250	0.45–0.55	0.60–0.90	0.045	0.045	1.80–2.20
9260	0.55–0.65	0.60–0.90	0.045	0.045	1.80–2.20

Part IV—Steel Castings[2]

S.A.E. SPECIFICATION 1235

(Proposed Revision of S.A.E. Standard)

MANUFACTURE

Process

The steel may be made by any process approved by the purchaser. Three grades are recognized: hard, medium and soft.

Cooling

All castings shall be allowed to become cold. They shall then be reheated uniformly to the proper temperature to refine the grain, and allowed to cool uniformly and slowly.

CHEMICAL COMPOSITION AND TESTS

Analysis

The castings supplied shall conform to the following chemical requirements in percentage on check analysis:

Carbon	As Required for Physical Properties
Phosphorus, not to exceed	0.05
Sulphur, not to exceed	0.05

Drillings

Drillings for analysis shall be so taken as to represent the average composition of the casting.

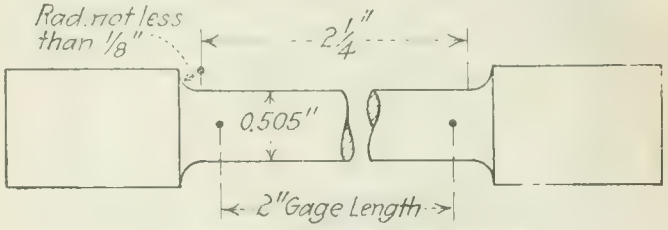


FIG. 9—ROUND TENSION TEST-SPECIMEN

PHYSICAL PROPERTIES AND TESTS

Tensile-Test

The tensile properties of finished castings shall conform to the following minimum requirements:

	Hard	Medium	Soft
Tensile-Strength, lb. per sq. in.	80,000	70,000	60,000
Yield-Point, lb. per sq. in.	36,000	31,500	27,000
Reduction of Area, per cent	20.0	25.0	30.0
Elongation in 2 In., per cent	15.0	18.0	22.0

Bend Test

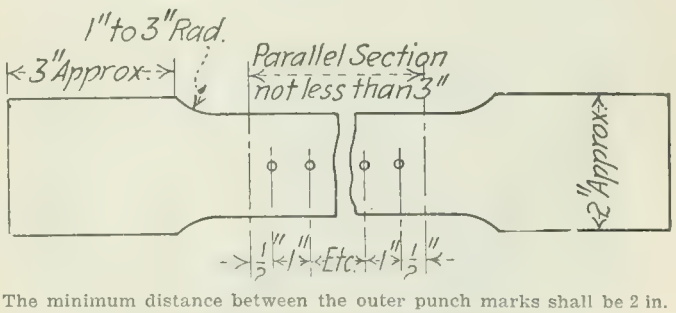
The test-specimens for soft castings shall bend cold through 120 deg., and for medium castings through 90 deg., around a 1-in. diameter pin without cracking on the outside. Hard castings shall not be subject to bend-test requirements.

Test to Destruction

For small or unimportant castings, a test to destruction on three castings from a lot may be substituted for the tension and bend tests. This test shall show the material to be ductile, free from injurious defects and suitable for the purpose intended. A lot shall consist of all castings from one melt in the same annealing charge. In case test-bars are cast separately, they shall be annealed with the lot they represent. The method of casting such test-bars, or casting test-bars attached to castings, shall be agreed upon by purchaser and manufacturer.

Tension Test

Tension test-specimens shall be machined to conform to the S.A.E. Standard Round Tension Test-Specimen, Fig. 9, and S.A.E. Standard Flat Tension Test-Specimen, Fig. 10. Bend test-specimens shall be machined to 1 x ½-in. section, with corners rounded to a radius not over 1/16 in.



The minimum distance between the outer punch marks shall be 2 in.

FIG. 10—FLAT TENSION TEST-SPECIMEN

Number of Tests

One tension and one bend test shall be made from each annealing charge. If more than one melt is represented in an annealing charge, one tension and one bend test shall be made from each melt.

[1] Steel 5165 has been omitted.

[2] This specification is substantially the same as Specification No. A27-14 of the American Society for Testing Materials.

Defective Test-Specimens

If any test-specimen shows defective machining or develops flaws it may be discarded, in which case another test-specimen may be selected by the manufacturer and the purchaser.

Retests

A retest shall be allowed if the percentage of elongation is less than that specified or if any part of the fracture is more than ¾ in. from the center of the gage length as indicated by scribe scratches marked on the test-specimen before testing.

Workmanship and Finish

Finished Castings

The finished castings shall conform substantially to the sizes and shapes of the patterns, shall be made in a workmanlike manner and be free from injurious defects.

Marking of Castings

Marking Castings

The manufacturer's identification mark and the pattern numbers assigned by the purchasers shall be cast on all castings of sufficient size, in such positions that they will not interfere with the service of the castings.

Inspection and Rejection

Defective Castings

Minor defects that do not impair the strength of the castings may, with the approval of the purchaser, be welded by an approved process. The defects shall first be cleaned out to solid metal and after welding the castings shall be annealed.

Hidden Defects

Castings offered for inspection shall not be painted or covered with any substance that will hide defects, nor rusted to such an extent as to hide defects.

Part V—Malleable Iron Castings[10]

(S.A.E. Standard)

Manufacture

Material

These specifications cover malleable iron castings for general automotive purposes.

Process

The castings shall be produced by either the air-furnace, open-hearth or electric-furnace process.

Physical Properties and Tests

Tensile-Test

The tensile properties of the test-specimens specified shall conform to the following minimum requirements:

Tensile-Strength, lb. per sq. in.	45,000
Elongation in 2 In., per cent	7.5

Special Tests

All castings, if of sufficient size, shall have cast thereon test-lugs of a size proportional to the thickness of the casting, but not exceeding ⅝ x ¾ in. in cross-section. On castings that are 24 in. or over in length, a test-lug shall be cast near each end. These test-lugs shall be attached to the casting at such a point that they will not interfere with the assembling of the castings, and may be broken off by the inspector.

If the purchaser or his representative so desires, a casting may be tested to destruction. Such a casting shall show good, tough malleable iron.

Tension Test-Specimens[11]

Tension test-specimens shall conform to S.A.E. Standard Tension Test-Specimen, Fig. 11. Test-specimens whose mean diameter at the smallest section is less than 19/32 in. will not be accepted for test.

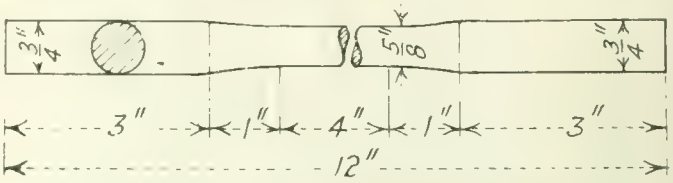


Fig. 11—Malleable Iron Tension Test-Specimen

Number of Test-Specimens

A set of three tension test-specimens shall be cast from each melt, without chills, using heavy risers of sufficient height to secure sound bars. The specimens shall be suitably marked for identification with the melt. Each set of specimens so cast shall be placed in some one oven containing castings to be annealed.

Number of Tests

After annealing, three tension test-specimens shall be selected by the inspector as representing the castings in the oven from which these specimens are taken.

Failures

If the first specimen conforms to the specified requirements, or if, in the event of failure of the first specimen, the second and third specimens conform to the requirements, the castings in that oven shall be accepted, except that any casting may be rejected if its test-lug shows that it has not been properly annealed. If either the second or third specimen fails to conform to the requirements, the entire contents of that oven shall be rejected.

Reannealing

Any castings rejected for insufficient annealing may be reannealed once. The reannealed castings shall be inspected and if the remaining test-lugs, or castings broken as specimens, show the castings to be thoroughly annealed, they shall be accepted; if not, they shall be finally rejected.

Workmanship and Finish

Workmanship

The castings shall conform substantially to the patterns or drawings furnished by the purchaser, and also to gages that may be specified in individual cases. The castings shall be made in a workmanlike manner. A variation of ⅛ in. per ft. will be permitted.

Finish

The castings shall be free from injurious defects.

Marking of Castings

The manufacturer's identification mark and the pattern numbers assigned by the purchaser shall be cast on all castings of sufficient size, in such positions that they will not interfere with the service of the castings.

Inspection and Rejection

Inspection

The inspector representing the purchaser shall have free entry at all times to all parts of the manufacturer's works that concern the manufacture of the castings ordered while work on the contract of the purchaser is being performed. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the castings are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Record of Tests

The manufacturer shall be required to keep a record

[10] This specification is practically the same as specification No. A47-19 of the American Society for Testing Materials.

[11] Tension test-specimens are not machined.

of each melt from which castings are produced, showing tensile-strength and elongation of test-specimens cast from such melts. These records shall be available and shown to the inspector whenever required.

Rejection

Castings that show injurious defects subsequent to their acceptance at the manufacturer's works may be rejected, and, if rejected, shall be replaced by the manufacturer free of cost to the purchaser.

Part VI—Definitions

(General Information)

Normalizing—Heating above the upper critical temperature followed by cooling freely in air.

Annealing—Heating above the upper critical temperature followed by slow cooling as desired.

Quenching—The operation of rapidly cooling in a suitable medium.

Drawing—Reheating after quenching for hardening, to some temperature below the lower limit of the critical range, followed by cooling as desired.

Case-Hardening—The operation of carburizing steel to a predetermined depth of case and subjecting it to a subsequent heat-treatment.

Carburizing—The operation of causing the absorption of carbon by steel when heated below its melting point in contact with carbonaceous material.

Case—The outer portion of a carburized part that has absorbed carbon from the carburizing medium.

Core—The inner portion of a carburized part that has not absorbed carbon from the carburizing medium.

Cyaniding—The operation of case-hardening by which the carburizing is accomplished by heating the steel in a melted cyanide salt.

Cold-Working—The operation of forming the metal, without the application of heat, by rolling, hammering, drawing, pressing or other means to obtain accurate size, fine finish or increased strength.

Hot-Working — The operation of rolling, hammering, pressing or extruding metal which has been made plastic by heating.

Yield-Point—The load per unit of original cross-section at which a marked increase in the deformation of the specimen occurs without increase of load. It is usually calculated from the load determined by the drop of the beam of the testing machine or by the use of dividers.

Tensile-Strength—The maximum load per unit of original cross-sectional area obtained before rupture.

Percentage Elongation—The percentage of increase in length of a tension test-specimen after rupture.

Percentage Reduction of Area—The percentage of decrease of cross-sectional area of a tension test-specimen after rupture.

Shore Hardness—The reading on a conventional scale determined by the rebound of the hammer of the Shore scleroscope on striking the surface of the specimen. (See proposed recommendation)

Brinell Hardness — The number obtained from the ratio between the load applied on and the spherical area of the impression made by a steel ball forced into the surface of the material tested. (See proposed recommendation)

Part VII—Test-Specimens

(Proposed Revision of S.A.E. Standard)

S.A.E. Steels shall be purchased on the basis of requirements as to chemical composition, and the specifications provided herein should be used in the purchase of the grades and types of steel covered by each. When the steel user desires physical tests on forged parts, bars or billets, the test-specimens shall be selected and prepared in accordance with the following standards.

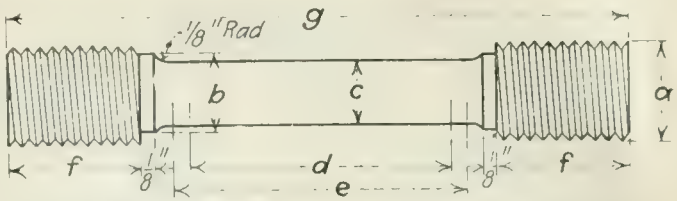


FIG. 12—PROPORTIONAL-SIZE ROUND TENSION TEST-SPECIMEN

Diameter of Stock, in.	$\frac{1}{2}$ to $\frac{3}{4}$	$\frac{3}{8}$ to $\frac{1}{2}$	$\frac{1}{4}$ to $\frac{3}{8}$
a, in.	0.500	0.375	0.250
b, in.	0.391	0.281	0.172
Diameter over Gage-Length (*c*), in.	0.375	0.250	0.125
Gage-Length (*d*), in.	1.500	1.000	0.500
e, in.	1.750	1.250	0.750
f, in. (Approximately)	0.750	0.500	0.375
g, in. (Approximately)	3.625	2.625	1.875

CONSTRUCTION

Tension and bend test-specimens shall be taken from the rolled or forged material, except that in the case of irregularly shaped forgings, they may be taken from a full-size prolongation. Test-specimens shall not be annealed or otherwise treated, except as specified in the following paragraph. Bend tests shall be made cold.

Tension and bend test-specimens for material that is to be annealed or otherwise treated before use shall, for rolled material, be cut from properly annealed or similarly treated short lengths of the full section of the piece and for forged material from the treated forgings.

The axis of tension and bend test-specimens for rolled bars and forgings of uniform cross-section of over 1½-in. thickness or diameter and for forgings of irregular sections shall, when practicable, be located at any point midway between the center and the outer surface when solid, and at any point midway between the inner and outer surfaces of the wall when bored, and shall be parallel to the axis of the piece in the direction in which the metal is most drawn out. Round tension test-specimens shall be machined to the form and dimensions shown in Fig. 9. The gage-length and fillets shall be ground or lap-polished free from scratches. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Plain ends for grips, threaded ends or self-aligning ball-ends may be used.

The bend test-specimens shall be ½ in. square in section and not over 6 in. in length with corners rounded to a radius of not over 1/16 in.

The axis of tension test-specimens for rolled bars and forgings of uniform cross-section 1½ in. or under in thickness or diameter shall be machined concentrically from the specimen. Round tension test-specimens may be machined to the form and dimensions shown in Fig. 9 or may be of larger dimensions provided the length of the pull-section equals 4½ times the square root of the area. The gage-length and fillets shall be ground or lap-polished free from scratches. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Plain ends for grips, threaded ends or self-aligning ball-ends may be used.

Bend test-specimens shall be ½ in. square in section and not over 6 in. in length with corners rounded to a radius of not over 1/16 in.

Round tension test-specimens for rolled bars or forgings of dimensions too small to permit the use

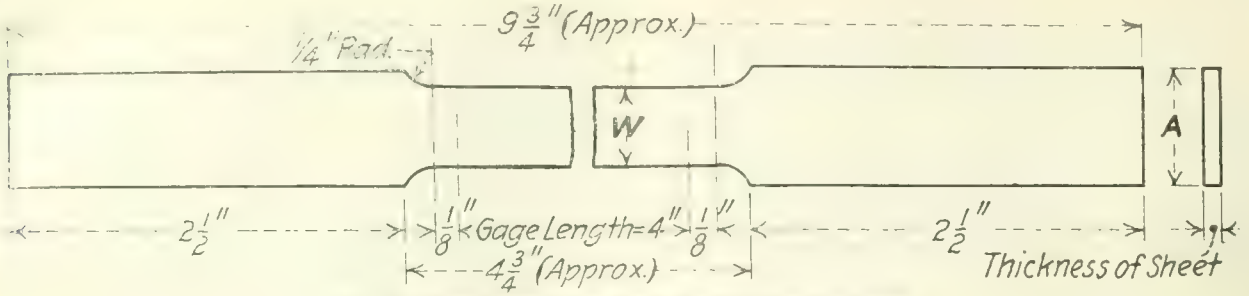


FIG. 13—PROPORTIONAL-SIZE FLAT TENSION TEST-SPECIMEN

	Up to 0.15	Over 0.15 to 0.50
Thickness of Sheet, in.		
Gage-Width (W), in.	0.50	0.75
Width of Grip (A), in.	0.75	1.00

of the standard full-size test-specimen, may be machined to the dimensions of the proportional-size round test-specimens shown in Fig. 12 and the accompanying table. The gage-length and fillets shall be ground or lap-polished free from scratches. The ends shall be of a form to fit the holders of a testing-machine in such a way that the load will be axial. Threaded or self-aligning ball-ends may be used. Plain-ends for grips are not recommended.

Flat tension and bend test-specimens for plates and shapes shall be of the full thickness of material as rolled and tensile test-specimens shall be machined to the form and dimensions shown in Fig. 10. The gage-width of test-specimens ¼ in. or less in thickness should be equal to five times the thickness, except that in no case shall the width be less than ¾ in. The gage-length should equal 24 times the thickness of the test-specimen, except that in no case shall it be less than 2 in. The gage-length on test-specimens shall be finished on all sides smooth and free from scratches.

Flat tension test-specimens for shapes or sheets of dimensions too small to permit the use of the standard full-size test-specimen may be machined to the dimensions of the proportional-size flat tension test-specimen shown in Fig. 13 and the accompanying table. The gage-length and fillets shall be ground or lap-polished free from scratches.

Tension test-specimens for malleable castings as specified in that specification shall conform to the shape and dimensions shown in Fig. 11 and shall *not* be machined.

NUMBER OF TESTS

Unless otherwise specified by the purchaser, one tension and one bend test shall be made from each melt; except that if material rolled from one melt differs ⅜ in. or more in thickness, one tension and one bend test shall be made from both the thickest and the thinnest material.

If any test-specimen shows defective machining or develops flaws, it may be discarded; in which case the manufacturer and the purchaser or his representative shall agree upon the selection of another test-specimen in its stead.

If the percentage of elongation of any tension test-specimen is less than that specified and any part of the fracture is more than ¾ in. from the center of the gage length of a 2-in. test-specimen or is outside the middle third of the gage-length of an 8-in. test-specimen, as indicated by divider scratches marked on the test-specimen before testing, a retest shall be allowed.

Part VIII—Hardness Tests

BRINELL HARDNESS TEST

(Proposed Revision of S.A.E. Recommended Practice)

Test Ball—The diameter of the ball shall be 10 mm., ± 0.0025 mm. (0.39370 in. ± 0.00098 in.). The weight applied shall be 3000 kg. (6600 lb.) for 30 sec.

Test Impression—The average diameter of the impression shall be obtained from two measurements at right angles to each other, made with an instrument having a reading error not over 0.05 mm. (0.001969 in.).

Test-Specimen—The surface of the specimen shall be free from scratches. The specimen shall be taken deep enough to represent the true composition of the material to be tested, and shall be maintained

BRINELL HARDNESS NUMBERS

Diameter of Impression, mm.	Brinell Hardness Numbers Loads in Kg.		Diameter of Impression, mm.	Brinell Hardness Numbers Loads in Kg.		Diameter of Impression, mm.	Brinell Hardness Numbers Loads in Kg.		Diameter of Impression, mm.	Brinell Hardness Numbers Loads in Kg.	
	3000	500		3000	500		3000	500		3000	500
2.00	945	158	3.25	352	59	4.50	179	30	5.75	105	18
2.05	899	150	3.30	341	57	4.55	174	29	5.80	103	17
2.10	857	143	3.35	331	55	4.60	170	28	5.85	101	17
2.15	817	136	3.40	321	53	4.65	167	28	5.90	99	17
2.20	780	130	3.45	311	52	4.70	163	27	5.95	97	16
2.25	745	124	3.50	302	50	4.75	159	27	6.00	96	16
2.30	712	119	3.55	293	49	4.80	156	26	6.05	94	16
2.35	682	114	3.60	285	48	4.85	152	25	6.10	92	15
2.40	654	109	3.65	277	46	4.90	149	25	6.15	90	15
2.45	627	104	3.70	269	45	4.95	146	24	6.20	89	15
2.50	602	100	3.75	262	44	5.00	143	24	6.25	87	15
2.55	578	96	3.80	255	42	5.05	140	23	6.30	86	14
2.60	555	93	3.85	248	41	5.10	137	23	6.35	84	14
2.65	534	89	3.90	241	40	5.15	134	22	6.40	83	14
2.70	514	86	3.95	235	39	5.20	131	22	6.45	81	14
2.75	495	83	4.00	229	38	5.25	128	21	6.50	80	13
2.80	478	80	4.05	223	37	5.30	126	21	6.55	78	13
2.85	461	77	4.10	217	36	5.35	123	21	6.60	77	13
2.90	444	74	4.15	212	35	5.40	121	20	6.65	75	13
2.95	429	72	4.20	207	34	5.45	118	20	6.70	74	12
3.00	415	69	4.25	201	34	5.50	116	19	6.75	73	12
3.05	401	67	4.30	197	33	5.55	114	19	6.80	72	12
3.10	388	65	4.35	192	32	5.60	111	19	6.85	70	12
3.15	375	63	4.40	187	31	5.65	109	18	6.90	69	12
3.20	363	61	4.45	183	31	5.70	107	18	6.95	68	11
									7.00	67	11

in a plane normal to the direction of the testing load.

Exceptions—This test should not be used on soft steels less than ½ in. thick or on areas small enough to permit deflection of the edges of the specimen owing to the flow from the ball depression.

SHORE HARDNESS TEST

(Proposed General Information)

The Shore hardness number is the reading obtained on an arbitrary scale ranging from 0 to 120, by the rebound of a small diamond-pointed hammer dropped from a fixed height. Two types of instrument are in common use; one in which the rebound is read directly on a vertical scale, and the other on which the reading is registered by the instrument on a recording dial. It is suggested that, unless special means are used to compensate for the variations in mass, form, surface, composition and physical condition of different specimens being tested, the user determine for himself the characteristic readings obtained on his particular product.

The scleroscope values shown in the accompanying charts of physical properties are average values obtained with the bulb or vertical-scale type of instrument under the conditions described in the Notes, the specimens tested having carefully polished, level surfaces, which are essential in obtaining satisfactory results.

Part IX—General Heat-Treatments

(Proposed Revision of General Information)

In applying detailed heat-treatments as outlined in this report it is recommended, in order to obtain uniform physical properties, that the final quench be made from the lowest temperature that will develop the maximum physical properties, bearing in mind that with thinner sections lower temperatures are required than with thicker sections.

CASE-HARDENING

Heat-Treatments I to V

The process of carburizing as considered in these Notes refers to the dry or pack method and does not take into consideration carburizing by the liquid or gaseous methods. The last two methods have extensive application but the operations depend to such a large extent on individual conditions such as size, shape and use for which these are intended that they cannot be covered by these general Notes.

The process of carburizing is usually divided into two methods.

(1) Quenching directly from the box
(2) Cooling slowly in the box

The first method prevents the formation of a cementite network and large grain-growth. The second method tends in many instances to lessen distortion but does not prevent the formation of a cementite network and large grain-growth. In Heat-Treatment V the first reheat, operation 3, is applied to refine the core and has a beneficial effect on the case. These two general methods are subdivided into specific types of heat-treatments that are applicable for parts of various compositions, shapes, uses and importance.

In case-hardening heat-treatments the drawing operation is not always used in commercial practice, but it is recommended in all cases as being in accord with the best metallurgical practice.

PHYSICAL PROPERTIES AND HEAT-TREATMENTS

Physical-Property Charts

In interpreting the charts of physical properties given in this report in Figs. 14 to 38 the following considerations should always be borne in mind.

The charts have been made as valuable as possible to the engineer by indicating what can be expected as the average product of a given composition when treated in the specific manner in 1½-in. sections. Generally on sizes larger than 1½ in., lower values will prevail and on sizes smaller than 1½ in., higher values will prevail. At the same time the data for the charts have been chosen so as to protect makers of heat-treated stock and parts from unreasonable demands.

For the sake of simplicity it has seemed advisable to use only average minimum figures for tensile-strength, yield-point, reduction of area and elongation, based on the following considerations, heat-treatment being constant:

(1) The lowest yield-points and tensile-strengths are produced with steels at the bottom of a given range in carbon
(2) The lowest reductions in area and elongations are produced with steels at the top of a given range in carbon

Thus, for Steel 1035, the average minimum yield-points and tensile-strengths are given as of a steel containing 0.30 per cent carbon; average minimum reductions of area and elongations as of a steel containing 0.40 per cent carbon.

The figures for hardness are conventional averages for the whole range of compositions within any given specification.

The charts include treatments and conservative physical tests on all S.A.E. Steels for which such charts have been prepared. For these charts the following applies:

(1) They indicate the physical properties which may be expected of a standard 0.505 x 2-in. test-specimen machined from rolled bars of 1½-in. diameter or square
(2) Heat-treatments given in the charts apply to rolled bars that were normalized or otherwise treated prior to heating and quenching as shown on individual charts

CASE-HARDENING TREATMENTS

Heat-Treatment I
1—Carburize
2—Quench
3—Draw

Heat-Treatment II
1—Carburize
2—Quench
3—Reheat
4—Quench
5—Draw

Heat-Treatment III
1—Carburize
2—Quench
3—Reheat
4—Quench
5—Reheat
6—Quench
7—Draw

Heat-Treatment IV
1—Carburize
2—Cool in box
3—Reheat
4—Quench
5—Draw

Heat-Treatment V
1—Carburize
2—Cool in box
3—Reheat
4—Quench
5—Reheat
6—Quench
7—Draw

HARDENING AND TOUGHENING TREATMENTS

Heat-Treatment VI
1—Heat
2—Quench
3—Draw

Heat-Treatment VII
1—Normalize
2—Reheat
3—Quench
4—Draw

Heat-Treatment VIII
1—Normalize
2—Reheat
3—Cool in furnace
4—Machine
5—Reheat
6—Quench
7—Draw

(3) Test-bars 0.505 in. in diameter and 2 in. long, machined from rolled bars after final treatment and tested under normal commercial conditions
(4) Brinell and scleroscope readings were taken at a distance from the center equal to half the radius and are not to be compared with surface readings on heat-treated bars or parts.

S.A.E. Steels 1010 *and* 1015

These Notes are not to be considered in any way art of the standard specifications for S.A.E. ls. They are added solely for the information sers of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

CHEMICAL COMPOSITION IN PERCENTAGE

Steel	1010	1015
Carbon	0.05-0.15	0.10-0.20
Manganese	0.30-0.60	0.30-0.60
Phosphorus	0.045 max.	0.045 max.
Sulphur	0.05 max.	0.05 max.

These steels are commonly used for seamless tubing and pressed-steel parts of many varieties. They are soft and ductile and will stand much deformation without cracking.

In a natural or annealed condition, these steels have low tensile-strength and should not be used where much strength is required. They are considerably stronger after cold-working; that is, the yield-point is raised by such working. This is important in view of the fact that many parts are used in cold-worked condition.

These compositions, when in the natural or annealed condition, should have the following approximate physical properties:

Yield-Point, lb./per sq. in.	28,000 to 36,000
Elongation in 2 In., per cent	40 to 30
Reduction of Area, per cent	65 to 55

It should be borne in mind that when these steels in cold-worked condition are heated for bending, brazing, welding or such operations the yield-point returns to that which is characteristic of the annealed or hot-worked material. This applies also to all materials the yield-point of which is increased by cold-working.

These steels do not machine freely. They will tear badly in turning, threading and broaching operations. It is possible, by quenching them in water from 1700 deg. fahr., no draw being required, to improve their machining qualities over those in the annealed condition. Such heat-treatment, however, produces very little increase in strength. These steels can be used for case-hardening, Heat-Treatment I being used when the strength of the core is not important.

Heat-Treatment II is recommended when maximum hardness only is required and distortion is not important. When maximum hardness of case and refinement of both the case and the core are desired, distortion again being unimportant, Heat-Treatment III should be used. When hardness, refinement of the case and the least possible distortion are required, Heat-Treatment IV should be used. When refinement of both the case and the core is desired, distortion not being important, Heat-Treatment V may be used.

Heat-Treatment 1010-*I and* 1015-*I*
1—Carburize at 1650 to 1700 deg. fahr.
2—Quench
3—Draw at 250 to 500 deg. fahr. is recommended

Heat-Treatment 1010-*II and* 1015-*II*
1—Carburize at 1650 to 1700 deg. fahr.
2—Quench from box
3—Reheat to 1400 to 1450 deg. fahr.
4—Quench
5—Draw at 250 to 500 deg. fahr. is recommended

Heat-Treatment 1010-*III and* 1015-*III*
1—Carburize at 1650 to 1700 deg. fahr.
2—Quench from box
3—Reheat to 1650 to 1700 deg. fahr.
4—Quench
5—Reheat to 1400 to 1450 deg. fahr.
6—Quench
7—Draw at 250 to 500 deg. fahr. is recommended

Heat-Treatment 1010-*IV and* 1015-*IV*
1—Carburize at 1650 to 1700 deg. fahr.
2—Cool in box
3—Reheat to 1400 to 1450 deg. fahr.
4—Quench
5—Draw at 250 to 500 deg. fahr. is recommended

Heat-Treatment 1010-*V and* 1015-*V*
1—Carburize at 1650 to 1700 deg. fahr.
2—Cool in box
3—Reheat to 1650 to 1700 deg. fahr.
4—Quench
5—Reheat to 1400 to 1450 deg. fahr.
6—Quench
7—Draw at 250 to 500 deg. fahr. is recommended

S.A.E. Steel 1020

These Notes are not to be considered in any way a part of the standard specifications for S.A.E. Steels. They are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.15-0.25
Manganese	0.30-0.60
Phosphorus	0.045 max.
Sulphur	0.05 max.

This steel is known to the trade as 0.20 carbon open-hearth steel, and often as machine steel. It forges well and machines better than S.A.E. Steels 1010 and 1015 but should not be considered as screw-machine stock. It can be used for a very large variety of forged, machined and case-hardened automotive parts where strength is not paramount.

Steel of this quality can be drawn into tubes and cold-rolled into forms and shapes for automotive parts. It can be also safely used interchangeably with S.A.E. Steels 1010 and 1015 for cold-worked shapes that do not require deep drawing.

When cold-worked, this steel will have a yield-point of 40,000 to 80,000 lb. per sq. in. in round sections not over ½ in. in diameter or in sheets or flats ¼ in. thick. Heat-treatment of this steel produces a desirable refinement of grain after rolling or forging. The following heat-treatment will often help the machining qualities of hot-rolled and forged stock:

Heat-Treatment 1020-*VI*
1—Heat to 1575 to 1675 deg. fahr.
2—Quench in water
3—Draw to required hardness

Case-hardening is the most important heat-treatment for this quality of steel. The particular case-hardening treatment depends upon the importance of the part to be treated and its shape and size. When hardness only is required, such parts may be subjected to Heat-Treatment II; when maximum hardness of the case and refinement of both the case and the core are desired, distortion again being unimportant, Heat-Treatment III should be used;

when a refined case and minimum distortion are required, Heat-Treatment IV should be used; when maximum refinement of both the case and the core is required Heat-Treatment V should be used.

When this steel is used for gears for which a high degree of accuracy and considerable strength are required, it is recommended that the carburizing operation be preceded by normalizing at 1650 to 1750 deg. fahr., which will improve the structure and tend to reduce the distortion caused by subsequent treatments.

Heat-Treatment 1020-*I*

1—Carburize at 1650 to 1700 deg. fahr.
2—Quench
3—Draw at 250 to 500 deg. fahr. is recommended

Heat-Treatment 1020-*II*

1—Carburize at 1650 to 1700 deg. fahr.
2—Quench from box
3—Reheat to 1400 to 1450 deg. fahr.
4—Quench
5—Draw at 250 to 500 deg. fahr. is recommended

Heat-Treatment 1020-*III*

1—Carburize at 1650 to 1700 deg. fahr.
2—Quench from box
3—Reheat to 1600 to 1650 deg. fahr.
4—Quench
5—Reheat to 1400 to 1450 deg. fahr.
6—Quench
7—Draw at 250 to 500 deg. fahr. is recommended

Heat-Treatment 1020-*IV*

1—Carburize at 1650 to 1700 deg. fahr.
2—Cool in box
3—Reheat to 1400 to 1450 deg. fahr.
4—Quench
5—Draw at 250 to 500 deg. fahr. is recommended

Heat-Treatment 1020-*V*

1—Carburize at 1650 to 1700 deg. fahr.
2—Cool in box
3—Reheat to 1600 to 1650 deg. fahr.
4—Quench
5—Reheat to 1400 to 1450 deg. fahr.
6—Quench
7—Draw at 250 to 500 deg. fahr. is recommended

[For physical-property chart see Fig. 14]

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.15-0.25
Manganese	0.30-0.60
Phosphorus	0.045 max.
Sulphur	0.05 max.

Quenched at 1600 to 1650 deg. fahr. in *water*.

The accompanying chart is intended as a guide to the proper heat-treatment of this steel and to the physical properties that may be expected of a standard 0.505 x 2-in. test-specimen machined from rolled bars *up to* 1½-*in. diameter or square.*

Brinell and scleroscope hardnesses are taken at a distance from the center equal to one-half the radius and are not to be compared with surface readings on heat-treated bars.

For bars over 1½-*in. diameter or square, this chart does not apply.*

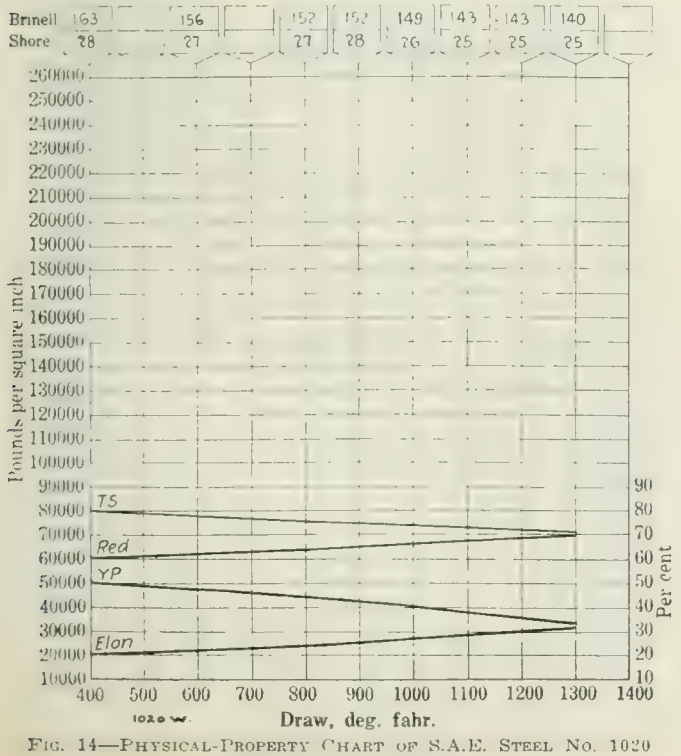


FIG. 14—PHYSICAL-PROPERTY CHART OF S.A.E. STEEL NO. 1020 QUENCHED IN WATER

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.20-0.30
Manganese	0.50-0.80
Phosphorus	0.045 max.
Sulphur	0.05 max.

Quenched at 1575 to 1650 deg. fahr. in *water*.

The accompanying chart is intended as a guide to the proper heat-treatment of this steel and to the physical properties that may be expected of a standard 0.505 x 2-in. test-specimen machined from rolled bars *up to* 1½-*in. diameter or square.*

Brinell and scleroscope hardnesses are taken at a distance from the center equal to one-half the radius and are not to be compared with surface readings on heat-treated bars.

For bars over 1½-*in. diameter or square, this chart does not apply.*

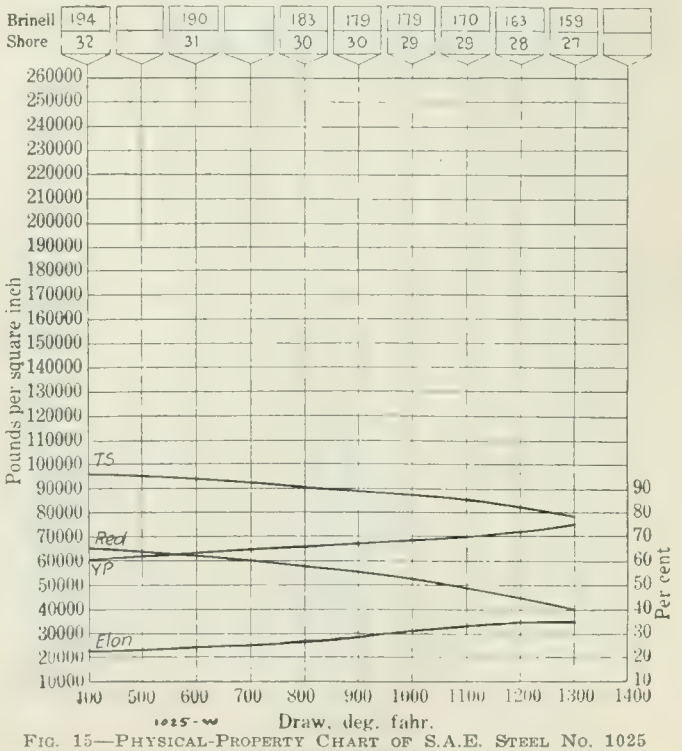


FIG. 15—PHYSICAL-PROPERTY CHART OF S.A.E. STEEL NO. 1025 QUENCHED IN WATER

S.A.E. Steels 1025 *and* 1030

These Notes are not to be considered in any way a part of the standard specifications for S.A.E. Steels. They are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

CHEMICAL COMPOSITION IN PERCENTAGE

Steel	1025	1030
Carbon	0.20-0.30	0.25-0.35
Manganese	0.50-0.80	0.50-0.80
Phosphorus	0.045 max.	0.045 max.
Sulphur	0.05 max.	0.05 max.

These steels will respond to heat-treatment better than Steel 1020. They can be used, therefore, for forged, machined or cold-worked parts requiring slightly higher physical properties than are obtainable with Steel 1020 and will have better machining qualities.

These steels should not be used for parts that are to be carburized. Heat-Treatment VI is recommended.

Heat-Treatment 1025-*VI and* 1030-*VI*
1—Heat to 1575 to 1650 deg. fahr.
2—Quench in water
3—Draw to required hardness

Where the maximum of uniformity in machining and in physical properties is desired, Heat-Treatment VII is recommended.

Heat-Treatment 1025-*VII and* 1030-*VII*
1—Normalize at 1700 to 1800 deg. fahr.
2—Heat to 1575 to 1650 deg. fahr.
3—Quench in water
4—Draw to required hardness

[For physical-property chart see Fig. 15]

S.A.E. Steels 1035 *and* 1040

These Notes are not to be considered in any way a part of the standard specifications for S.A.E. Steels. They are added solely for the information

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.30-0.40
Manganese	0.50-0.80
Phosphorus	0.045 max.
Sulphur	0.05 max.

Quenched at 1525 to 1575 deg. fahr. in *oil.*

The accompanying chart is intended as a guide to the proper heat-treatment of this steel and to the physical properties that may be expected of a standard 0.505 x 2-in. test-specimen machined from rolled bars *up to* 1½-*in. diameter or square.*

Brinell and scleroscope hardnesses are taken at a distance from the center equal to one-half the radius and are not to be compared with surface readings on heat-treated bars.

For bars over 1½-*in. diameter or square, this chart does not apply.*

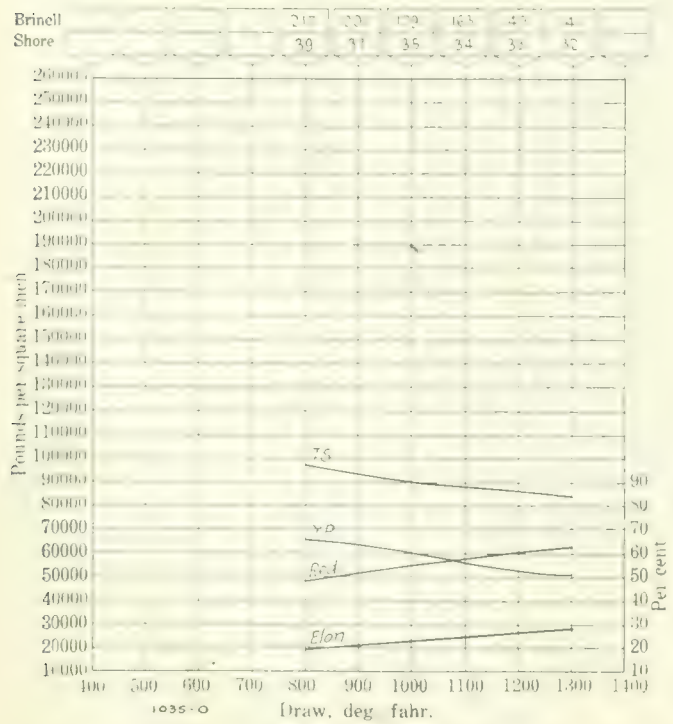


FIG. 16—PHYSICAL-PROPERTY CHART OF S.A.E. STEEL NO. 1035 QUENCHED IN OIL

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.30-0.40
Manganese	0.50-0.80
Phosphorus	0.45 max.
Sulphur	0.05 max.

Quenched at 1525 to 1575 deg. fahr. in *water.*

The accompanying chart is intended as a guide to the proper heat-treatment of this steel and to the physical properties that may be expected of a standard 0.505 x 2-in. test-specimen machined from rolled bars *up to* 1½-*in. diameter or square.*

Brinell and scleroscope hardnesses are taken at a distance from the center equal to one-half the radius and are not to be compared with surface readings on heat-treated bars.

For bars over 1½-*in. diameter or square, this chart does not apply.*

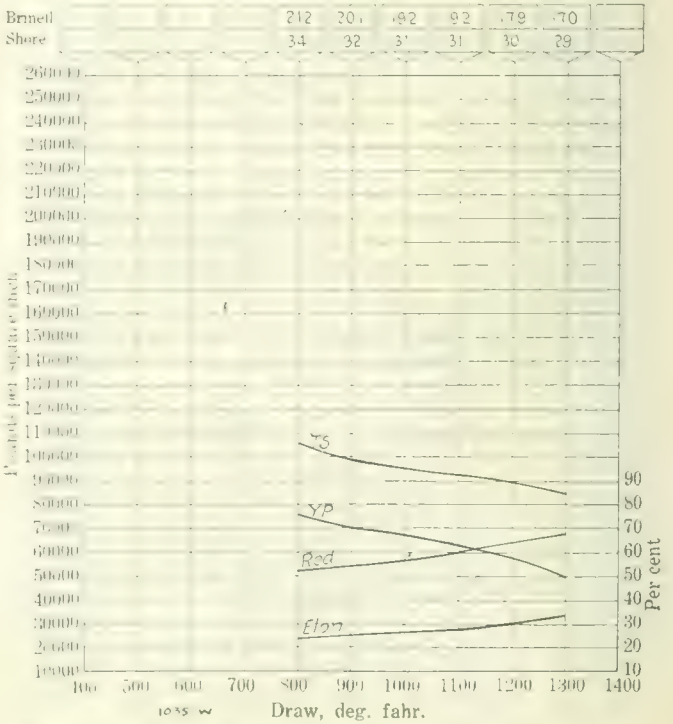


FIG. 17—PHYSICAL-PROPERTY CHART OF S.A.E. STEEL NO. 1035 QUENCHED IN WATER

of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

CHEMICAL COMPOSITION IN PERCENTAGE

Steel	1035	1040
Carbon	0.30-0.40	0.35-0.45
Manganese	0.50-0.80	0.50-0.80
Phosphorus	0.045 max.	0.045 max.
Sulphur	0.05 max.	0.05 max.

These are medium carbon steels possessing good machining properties and are suitable for small and medium sizes of plain carbon-steel forgings where moderate physical properties are desired. For general purposes Heat-Treatment VI is satisfactory.

Heat-Treatment 1035-*VI and* 1040-*VI*

1—Heat to 1525 to 1575 deg. fahr.
2—Quench
3—Draw to required hardness

Where maximum development of physical properties is desired as in the larger sizes of forgings Heat-Treatment VII is recommended.

Heat-Treatment 1035-*VII and* 1040-*VII*

1—Normalize at 1650 to 1750 deg. fahr.
2—Heat to 1525 to 1575 deg. fahr.
3—Quench
4—Draw to required hardness

[For physical-property charts see Figs. 16 and 17]

S.A.E. Steels 1045, 1046 *and* 1050

These Notes are not to be considered in any way a part of the standard specifications for S.A.E. Steels. They are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

CHEMICAL COMPOSITION IN PERCENTAGE

Steel	1045	1046	1050
Carbon	0.40-0.50	0.40-0.50	0.45-0.55
Manganese	0.50-0.80	0.30-0.50	0.50-0.80
Phosphorus	0.045 max.	0.045 max.	0.045 max.
Sulphur	0.05 max.	0.05 max.	0.05 max.

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.40-0.50
Manganese	0.50-0.80
Phosphorus	0.045 max.
Sulphur	0.05 max.

Quenched at 1475 to 1525 deg. fahr. in *oil.*

The accompanying chart is intended as a guide to the proper heat-treatment of this steel and to the physical properties that may be expected of a standard 0.505 x 2-in. test-specimen machined from rolled bars *up to* 1½*-in. diameter or square.*

Brinell and scleroscope hardnesses are taken at a distance from the center equal to one-half the radius and are not to be compared with surface readings on heat-treated bars.

For bars over 1½*-in. diameter or square, this chart does not apply.*

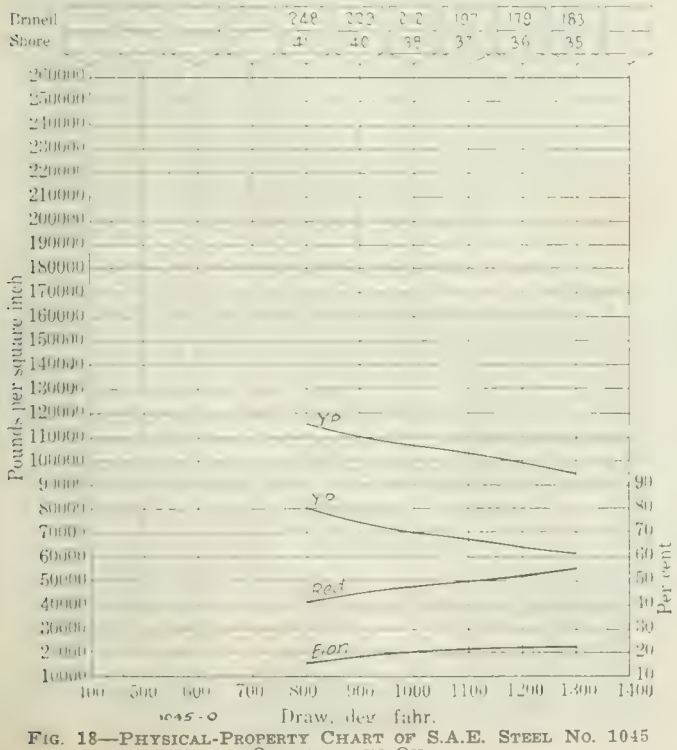


FIG. 18—PHYSICAL-PROPERTY CHART OF S.A.E. STEEL NO. 1045 QUENCHED IN OIL

Quenched at 1475 to 1525 deg. fahr. in *water.*

The accompanying chart is intended as a guide to the proper heat-treatment of this steel and to the physical properties that may be expected of a standard 0.505 x 2-in. test-specimen machined from rolled bars *up to* 1½*-in. diameter or square.*

Brinell and scleroscope hardnesses are taken at a distance from the center equal to one-half the radius and are not to be compared with surface readings on heat-treated bars.

For bars over 1½*-in. diameter or square, this chart does not apply.*

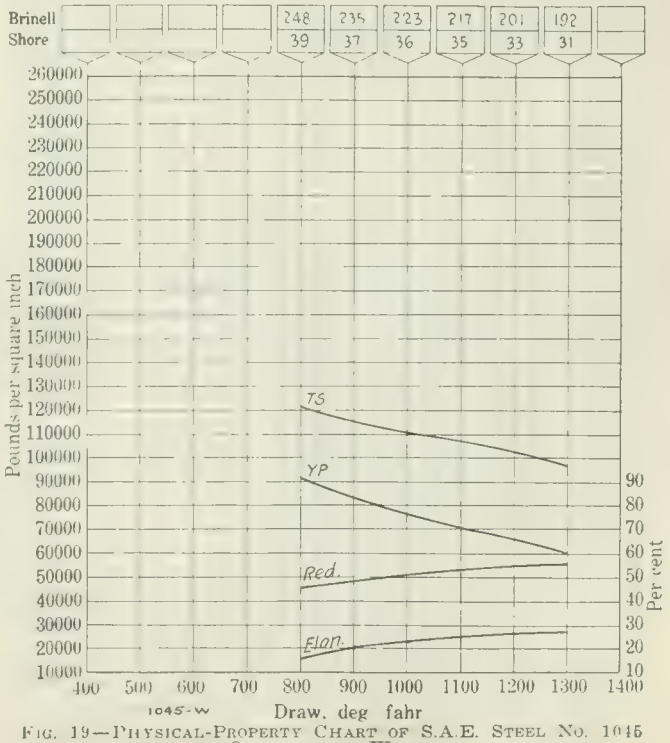


FIG. 19—PHYSICAL-PROPERTY CHART OF S.A.E. STEEL NO. 1045 QUENCHED IN WATER

These are medium carbon steels intended for the larger sizes of plain carbon-steel forgings used in automotive construction. They can also be used for a wide range of parts machined from bar stock.

Steel 1046 is the same as Steel 1045 except for a lower manganese-content and is intended for gears that are to ...ter-quenched.

... general purposes Heat-Treatment VI will produce ...esired physical properties.

...t-Treatment 1045-*VI*, 1046-*VI and* 1050-*VI*
1—Heat to 1500 to 1550 deg. fahr.
2—Quench in oil or water, depending upon size and shape of part
3—Draw to required hardness

Where maximum development of physical properties is desired, Heat-Treatment VII is recommended.

Heat-Treatment 1045-*VII*, 1046-*VII and* 1050-*VII*
1—Normalize at 1600 to 1700 deg. fahr.
2—Reheat to 1475 to 1525 deg. fahr.
3—Quench in oil or water, depending upon size and shape of part
4—Draw to required hardness

For parts such as gears that are to be machined after forging and before treatment, Heat-Treatment VIII is recommended.

Heat-Treatment 1045-*VIII*, 1046-*VIII and* 1050-*VIII*
1—Normalize at 1600 to 1700 deg. fahr.
2—Reheat to 1400 to 1450 deg. fahr.
3—Cool in furnace
4—Machine
5—Reheat to 1475 to 1525 deg. fahr.
6—Quench
7—Draw to required hardness

[For physical-property charts see Figs. 18 and 19]

S.A.E. Steel 1095

These Notes are not to be considered in any way a part of the standard specifications for S.A.E. Steels. They are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.90-1.05
Manganese	0.25-0.50
Phosphorus	0.04 max.
Sulphur	0.05 max.

This steel is used chiefly in leaf-springs and occasionally in certain coiled springs. The heat-treatment of such parts is dependent upon the method of manufacture.

For those cases where the user desires to heat-treat this material in plain or simple shapes other than leaf-springs, Heat-Treatment VI is recommended.

Heat-Treatment 1095-*VI*
1—Heat to 1400 to 1450 deg. fahr.
2—Quench in oil, water or brine, depending on size and shape of part
3—Draw to required hardness

S.A.E. Steel 2315

These Notes are not to be considered in any way a part of the standard specifications for S.A.E. Steels. They are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.10-0.20
Manganese	0.30-0.60
Phosphorus	0.04 max.
Sulphur	0.045 max.
Nickel	3.25-3.75

This steel is intended primarily for case-hardening. Parts made from it may be subjected to Heat-Treatment II when maximum hardness only is required and distortion is not important; to Heat-Treatment III when maximum hardness of the case and maximum refinement of both the case and the core are desired, distortion again being unimportant; to Heat-Treatment IV when hardness, refinement of the case and the least possible distortion are required; and to Heat-Treatment V when refinement of both the case and the core is desired, distortion not being important.

When these steels are used for gears for which a high degree of accuracy and strength is required, it is recommended that the carburizing operation be preceded by normalizing at 1650 to 1750 deg. fahr., which will improve the structure and tend to reduce the distortion caused by subsequent treatments.

Heat-Treatment 2315-*II*
1—Carburize at 1600 to 1650 deg. fahr.
2—Quench from box in oil
3—Reheat to 1350 to 1400 deg. fahr.
4—Quench
5—Draw at 250 to 500 deg. fahr. is recommended

Heat-Treatment 2315-*III*
1—Carburize at 1600 to 1650 deg. fahr.
2—Quench from box in oil
3—Reheat to 1500 to 1550 deg. fahr.
4—Quench in oil
5—Reheat to 1350 to 1400 deg. fahr.
6—Quench
7—Draw at 250 to 500 deg. fahr. is recommended

Heat-Treatment 2315-*IV*
1—Carburize at 1600 to 1650 deg. fahr.
2—Cool in box
3—Reheat to 1375 to 1425 deg. fahr.
4—Quench
5—Draw at 250 to 500 deg. fahr. is recommended

Heat-Treatment 2315-*V*
1—Carburize at 1600 to 1650 deg. fahr.
2—Cool in box
3—Reheat to 1500 to 1550 deg. fahr.
4—Quench in oil
5—Reheat to 1350 to 1400 deg. fahr.
6—Quench
7—Draw at 250 to 500 deg. fahr. is recommended

S.A.E. Steel 2320

These Notes are not to be considered in any way a part of the standard specifications for S.A.E. Steels. They are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.15-0.25
Manganese	0.50-0.80
Phosphorus	0.04 max.
Sulphur	0.045 max.
Nickel	3.25-3.75

Steel 2320 is not recommended for case-hardening except for massive parts because of the sacrifice to ductility and support of the core resulting from the higher

carbon. Subsequent to carbonizing, great care must be exercised in treatments to minimize brittleness of the core.

Carburized parts made from this steel may be subjected to Heat-Treatment II when maximum hardness only is required and distortion is not important. When maximum hardness of the case and maximum refinement of both the case and the core are desired, distortion again being unimportant, Heat-Treatment III should be used. When hardness, refinement of the case and least possible distortion are required, Heat-Treatment IV should be used. When refinement of both the case and core is desired, distortion not being important, Heat-Treatment V should be used. When these steels are used for gears for which a high degree of accuracy and strength is required, it is recommended that the carburizing operation be preceded by normalizing at 1650 to 1750 deg. fahr., which will improve the structure and tend to reduce the distortion caused by subsequent treatments.

Heat-Treatment 2320-*II*

1—Carburize at 1600 to 1650 deg. fahr.
2—Quench from box in oil
3—Reheat to 1350 to 1400 deg. fahr.
4—Quench
5—Draw at 250 to 500 deg. fahr. is recommended

Heat-Treatment 2320-*III*

1—Carburize at 1600 to 1650 deg. fahr.
2—Quench from box in oil
3—Reheat to 1500 to 1550 deg. fahr.
4—Quench in oil
5—Reheat to 1350 to 1400 deg. fahr.
6—Quench
7—Draw at 250 to 500 deg. fahr. is recommended

Heat-Treatment 2320-*IV*

1—Carburize at 1600 to 1650 deg. fahr.
2—Cool in box
3—Reheat to 1375 to 1425 deg. fahr.
4—Quench
5—Draw at 250 to 500 deg. fahr. is recommended

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.15-0.25
Manganese	0.50-0.80
Phosphorus	0.04 max.
Sulphur	0.045 max.
Nickel	3.25-3.75

Normalized at 1650 to 1750 deg. fahr.
Quenched at 1475 to 1525 deg. fahr. in *oil.*

The accompanying chart is intended as a guide to the proper heat-treatment of this steel and to the physical properties that may be expected of a standard 0.505 x 2-in. test-specimen machined from rolled bars *up to* 1½*-in. diameter or square.*

Brinell and scleroscope hardnesses are taken at a distance from the center equal to one-half the radius and are not to be compared with surface readings on heat-treated bars.

For bars over 1½*-in. diameter or square, this chart does not apply.*

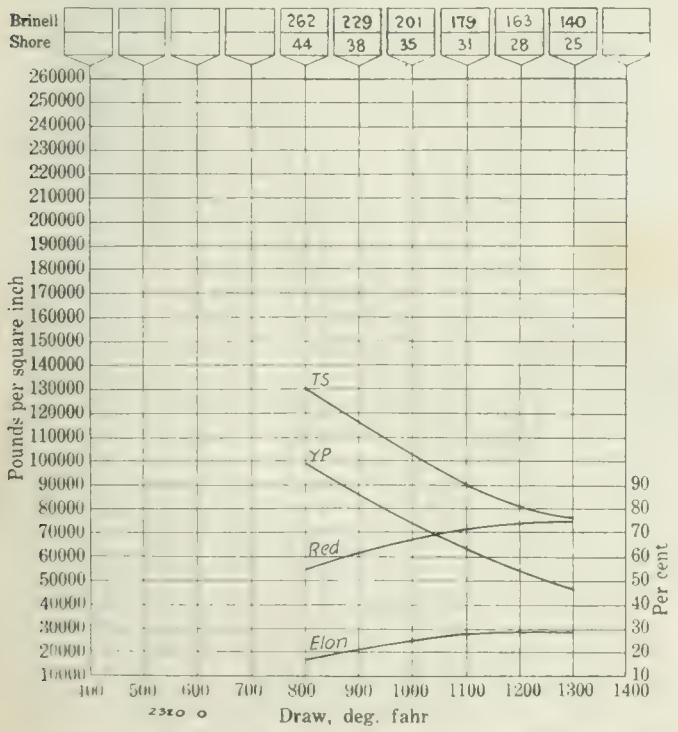


Fig. 20—Physical-Property Chart of S.A.E. Steel No. 2320 Quenched in Oil

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.15-0.25
Manganese	0.50-0.80
Phosphorus	0.04 max.
Sulphur	0.045 max.
Nickel	3.25-3.75

Normalized at 1650 to 1750 deg. fahr.
Quenched at 1475 to 1525 deg. fahr. in *water.*

The accompanying chart is intended as a guide to the proper heat-treatment of this steel and to the physical properties that may be expected of a standard 0.505 x 2-in. test-specimen machined from rolled bars *up to* 1½*-in. diameter or square.*

Brinell and scleroscope hardnesses are taken at a distance from the center equal to one-half the radius and are not to be compared with surface readings on heat-treated bars.

For bars over 1½*-in. diameter or square, this chart does not apply.*

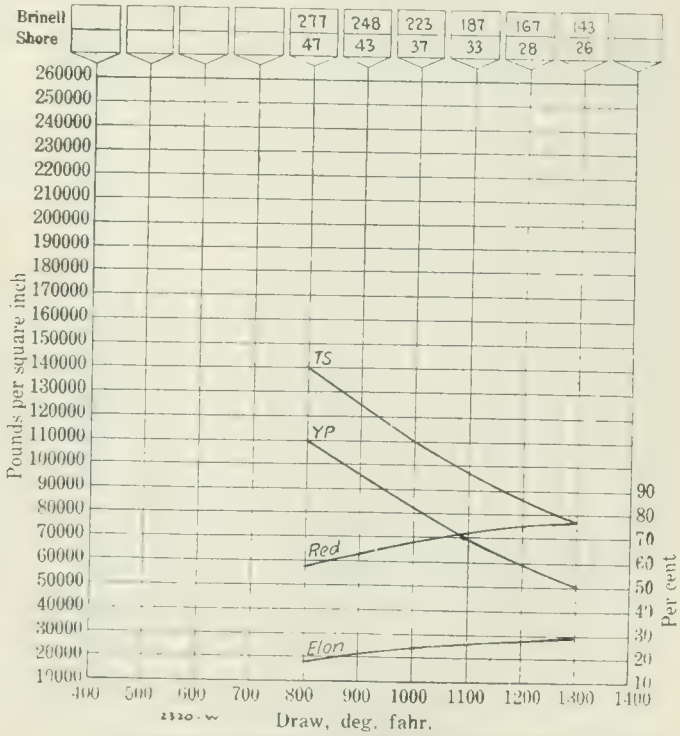


Fig. 21—Physical-Property Chart of S.A.E. Steel No. 2320 Quenched in Water

Heat-Treatment 2320-V

1—Carburize at 1600 to 1650 deg. fahr.
2—[illegible]
3—Reheat to 1500 to 1550 deg. fahr.
4—Quench in oil
5—Reheat to 1350 to 1400 deg. fahr.
6—Quench
7—Draw at 250 to 500 deg. fahr. is recommended

As the structure of forgings is less uniform than that of bar stock in most cases, either in the individual piece or between different pieces, normalizing as in Heat-Treatment VII is recommended as the preliminary treatment for all forgings, but the desired physical properties of bar stock can be obtained generally without normalizing, as in Heat-Treatment VI.

Heat-Treatment 2320-VI

1—Heat to 1475 to 1525 deg. fahr.
2—Quench
3—Draw to required hardness

For structural purposes forged parts should be given Heat-Treatment VII which will develop the desired physical properties.

Heat-Treatment 2320-VII

1—Normalize at 1650 to 1750 deg. fahr.
2—Heat to 1475 to 1525 deg. fahr.
3—Quench
4—Draw to required hardness

[For physical-property charts see Figs. 20 and 21]

S.A.E. Steels 2330 *and* 2335

These Notes are not to be considered in any way a part of the standard specifications for S.A.E. Steels. They are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.25-0.35
Manganese	0.50-0.80
Phosphorus	0.04 max.
Sulphur	0.045 max.
Nickel	3.25-3.75

Normalized at 1650 to 1750 deg. fahr.
Quenched at 1450 to 1500 deg. fahr. in *oil.*

The accompanying chart is intended as a guide to the proper heat-treatment of this steel and to the physical properties that may be expected of a standard 0.505 x 2-in. test-specimen machined from rolled bars *up to* 1½*-in. diameter or square.*

Brinell and scleroscope hardnesses are taken at a distance from the center equal to one-half the radius and are not to be compared with surface readings on heat-treated bars.

For bars over 1½*-in. diameter or square, this chart does not apply.*

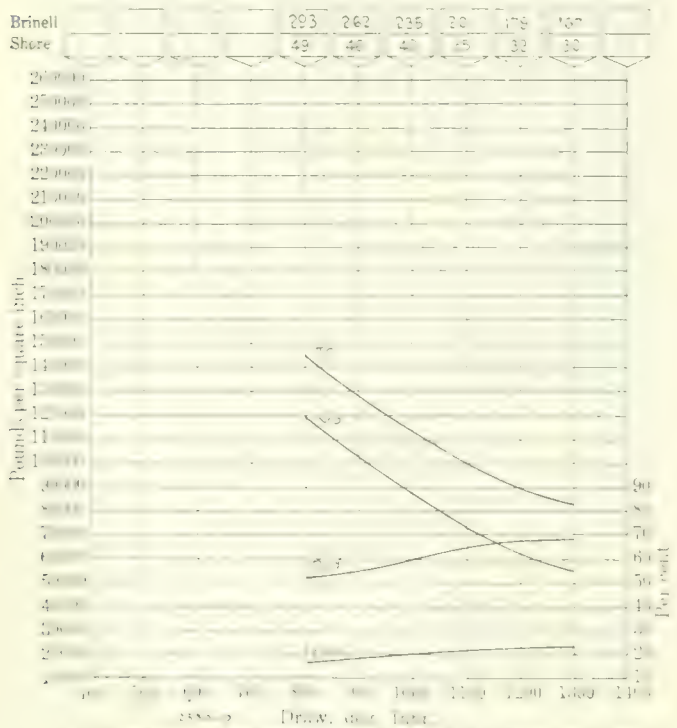


Fig. [illegible]—Physical-Property Chart of S.A.E. Steel No. 2330 Quenched in Oil

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.25-0.35
Manganese	0.50-0.80
Phosphorus	0.04 max.
Sulphur	0.045 max.
Nickel	3.25-3.75

Normalized at 1625 to 1725 deg. fahr.
Quenched at 1450 to 1500 deg. fahr. in *water.*

The accompanying chart is intended as a guide to the proper heat-treatment of this steel and to the physical properties that may be expected of a standard 0.505 x 2-in. test-specimen machined from rolled bars *up to* 1½*-in. diameter or square.*

Brinell and scleroscope hardnesses are taken at a distance from the center equal to one-half the radius and are not to be compared with surface readings on heat-treated bars.

For bars over 1½*-in. diameter or square, this chart does not apply.*

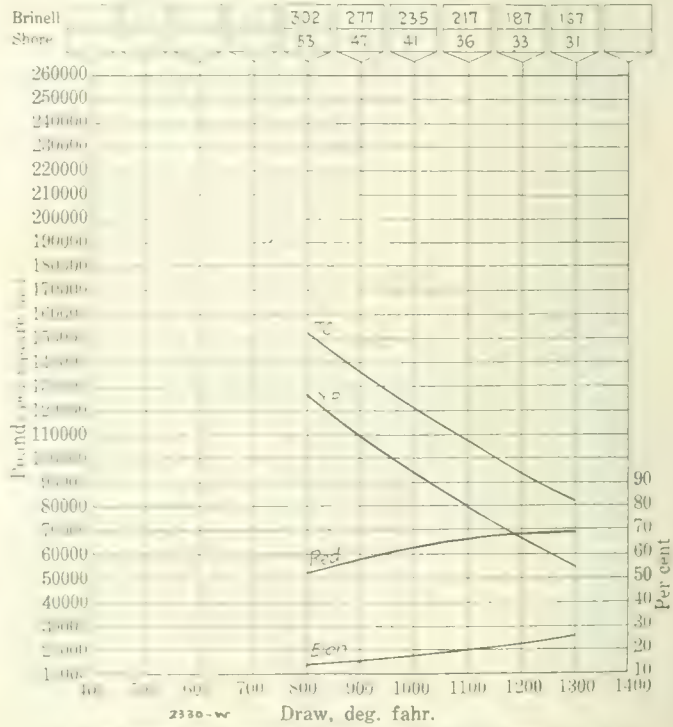


Fig. 21—Physical-Property Chart of S.A.E. Steel No. 2330 Quenched in Water

CHEMICAL COMPOSITION IN PERCENTAGE

Steels	2330	2335
Carbon	0.25-0.35	0.30-0.40
Manganese	0.50-0.80	0.50-0.80
Phosphorus	0.04 max.	0.04 max.
Sulphur	0.045 max.	0.045 max.
Nickel	3.25-3.75	3.25-3.75

These steels are primarily for heat-treated automotive parts when considerable strength and toughness are sought. *They should not be case-hardened.*

As the structure of forgings is less uniform than that of bar stock in most cases, either in the individual piece or between different pieces, normalizing as in Heat-Treatment VII is recommended as the preliminary treatment for all forgings, but the desired physical properties of bar stock can be obtained generally without normalizing, as in Heat-Treatment VI.

Heat-Treatment 2330-*VI and* 2335-*VI*
1—Heat to 1450 to 1500 deg. fahr.
2—Quench
3—Draw to required hardness

Heat-Treatment 2330-*VII and* 2335-*VII*
1—Normalize at 1650 to 1750 deg. fahr.
2—Heat to 1450 to 1500 deg. fahr.
3—Quench
4—Draw to required hardness

[For physical-property charts see Figs. 22 and 23]

S.A.E. Steels 2340 *and* 2345

These Notes are not to be considered in any way a part of the standard specifications for S.A.E. Steels. They are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

CHEMICAL COMPOSITION IN PERCENTAGE

Steels	2340	2345
Carbon	0.35-0.45	0.40-0.50
Manganese	0.50-0.80	0.50-0.80
Phosphorus	0.04 max.	0.04 max.
Sulphur	0.045 max.	0.045 max.
Nickel	3.25-3.75	3.25-3.75

These nickel steels are not widely used, but are available for certain purposes, the carbon content being higher than generally used, greater hardness is obtained by quenching and as increased brittleness accompanies the greater hardness, the heat-treatments given must be modified to meet such conditions.

As the structure of forgings is less uniform than that of bar stock in most cases, either in the individual piece or between different pieces, normalizing as in Heat-Treatment VII is recommended as the preliminary treatment for all forgings, but the desired physical properties of bar stock can be obtained generally without normalizing, as in Heat-Treatment VI.

Heat-Treatment 2340-*VI and* 2345-*VI*
1—Heat to 1425 to 1475 deg. fahr.
2—Quench
3—Draw to required hardness

Heat-Treatment 2340-*VII and* 2345-*VII*
1—Normalize at 1625 to 1725 deg. fahr.
2—Heat to 1425 to 1475 deg. fahr.
3—Quench
4—Draw to required hardness

For parts that are to be machined after forging and before heat-treatment, Heat-Treatment VIII is recommended.

Heat-Treatment 2345-*VIII*
1—Normalize at 1625 to 1675 deg. fahr.
2—Reheat to 1400 to 1450 deg. fahr.
3—Cool in furnace
4—Machine
5—Reheat to 1425 to 1475 deg. fahr.
6—Quench in oil
7—Draw to required hardness

[For physical-property chart see Fig. 24]

S.A.E. Steel 2350

These Notes are not to be considered in any way a part of the standard specifications for S.A.E. Steels. They are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.35-0.45
Manganese	0.50-0.80
Phosphorus	0.04 max.
Sulphur	0.045 max.
Nickel	3.25-3.75

Normalized at 1625 to 1725 deg. fahr.
Quenched at 1425 to 1475 deg. fahr. in *oil.*

The accompanying chart is intended as a guide to the proper heat-treatment of this steel and to the physical properties that may be expected of a standard 0.505 x 2-in. test-specimen machined from rolled bars *up to* 1½-*in. diameter or square.*

Brinell and scleroscope hardnesses are taken at a distance from the center equal to one-half the radius and are not to be compared with surface readings on heat-treated bars.

For bars over 1½-*in. diameter or square, this chart does not apply.*

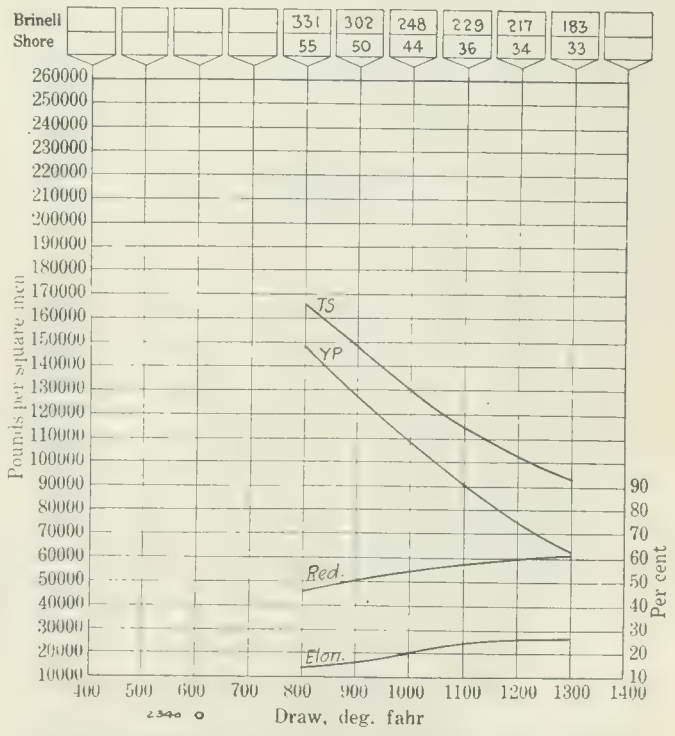


FIG. 24—PHYSICAL-PROPERTY CHART OF S.A.E. STEEL NO 2340 QUENCHED IN OIL

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.45-0.55
Manganese	0.50-0.80
Phosphorus	0.04 max.
Sulphur	0.045 max.
Nickel	3.25-3.75

This steel is provided to meet the requirements of ear manufacturers for gears of large section.

For parts, such as gears, that are to be machined after rging and before treatment, Heat-Treatment VIII is ommended.

Heat-Treatment 2350-*VIII*

1—Normalize at 1600 to 1650 deg. fahr.
2—Reheat to 1375 to 1425 deg. fahr.
3—Cool in furnace
4—Machine
5—Reheat to 1400 to 1450 deg. fahr.
6—Quench in oil
7—Draw to required hardness

S.A.E. Steel 2512

These Notes are not to be considered in any way a part of the standard specifications for S.A.E. Steels. They are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.17 max.
Manganese	0.30-0.60
Phosphorus	0.04 max.
Sulphur	0.045 max.
Nickel	4.50-5.25

This steel is used for case-hardened parts that require an exceptionally tough core after heat-treatment.

When it is used for gears for which a high degree of accuracy and considerable strength are required, it is recommended that the carburizing operation be preceded by either a normalizing treatment or a quench and drawing operation, which will improve the structure and machinability and tend to reduce the distortion caused by subsequent treatments.

When it is necessary to machine parts made of this steel after carburizing, the nickel content should be maintained as near the lower limit as possible.

For parts that are to be carburized Heat-Treatment IV is recommended.

Heat-Treatment 2512-*IV*

1—Carburize at 1600 to 1650 deg. fahr.
2—Cool in box
3—Reheat to 1400 to 1450 deg. fahr.
4—Quench in oil
5—Draw at 250 to 500 deg. fahr. is recommended

Heat-Treatment 2512-*V*

1—Carburize at 1600 to 1650 deg. fahr.
2—Cool in box
3—Reheat to 1500 to 1550 deg. fahr.
4—Quench in oil
5—Reheat to 1350 to 1400 deg. fahr.
6—Quench in oil
7—Draw at 250 to 500 deg. fahr. is recommended

S.A.E. Steels 3115 *and* 3120

These Notes are not to be considered in any way a part of the standard specifications for S.A.E. Steels. They are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

CHEMICAL COMPOSITION IN PERCENTAGE

Steel	3115	3120
Carbon	0.10-0.20	0.15-0.25
Manganese	0.30-0.60	0.30-0.60
Phosphorus	0.04 max.	0.04 max.
Sulphur	0.04 max.	0.045 max.
Nickel	1.00-1.50	1.00-1.50
Chromium	0.45-0.75	0.45-0.75

These steels are intended primarily for case-hardening but can also be used for structural parts with suitable heat-treatment such as VI or VII.

Carburized parts made from these steels may be subjected to Heat-Treatment II when hardness only is required and distortion is not important. When maximum hardness of the case and maximum refinement of both the case and the core are desired, distortion again being unimportant, Heat-Treatment III should be used. When hardness, refinement of the case and the least possible distortion are required, Heat-Treatment IV should be used. When refinement of both the case and the core is desired, distortion not being important, Heat-Treatment V should be used.

Steel 3120 is not recommended for case-hardening except for massive parts because of the sacrifice to ductility and support of the core resulting from the higher carbon. Subsequent to carbonizing, great care must be exercised in treatments to minimize the brittleness of the core.

When these steels are used for gears for which a high degree of accuracy and considerable strength are required, it is recommended that the carburizing operation be preceded by normalizing at 1650 to 1750 deg. fahr., which will improve the structure and tend to reduce the distortion caused by subsequent treatments.

Heat-Treatment 3115-*II and* 3120-*II*

1—Carburize at 1625 to 1675 deg. fahr.
2—Quench from box in oil
3—Reheat to 1400 to 1450 deg. fahr.
4—Quench
5—Draw at 250 to 500 deg. fahr. is recommended

Heat-Treatment 3115-*III and* 3120-*III*

1—Carburize at 1625 to 1675 deg. fahr.
2—Quench from box in oil
3—Reheat to 1525 to 1575 deg. fahr.
4—Quench in oil
5—Reheat to 1375 to 1425 deg. fahr.
6—Quench
7—Draw at 250 to 500 deg. fahr. is recommended

Heat-Treatment 3115-*IV and* 3120-*IV*

1—Carburize at 1625 to 1675 deg. fahr.
2—Cool in box
3—Reheat to 1400 to 1450 deg. fahr.
4—Quench
5—Draw at 250 to 500 deg. fahr. is recommended

Heat-Treatment 3115-*V and* 3120-*V*

1—Carburize at 1625 to 1675 deg. fahr.
2—Cool in box
3—Reheat to 1525 to 1575 deg. fahr.
4—Quench in oil
5—Reheat to 1375 to 1425 deg. fahr.
6—Quench
7—Draw at 250 to 500 deg. fahr. is recommended

As the structure of forgings is less uniform than that of bar stock in most cases, either in the individual piece or between different pieces, normalizing as in Heat-

Treatment VII is recommended as the preliminary treatment for all forgings but the desired physical properties of bar stock may be obtained generally without normalizing, as in Heat-Treatment VI.

Heat-Treatment 3120-*VI*

1—Heat to 1575 to 1625 deg. fahr.
2—Quench
3—Draw to required hardness

Heat-Treatment 3120-*VII*

1—Normalize at 1650 to 1750 deg. fahr.
2—Heat to 1575 to 1625 deg. fahr.
3—Quench
4—Draw to required hardness

[For physical-property charts see Figs. 25 and 26]

S.A.E. Steels 3125 *and* 3130

These Notes are not to be considered in any way a part of the standard specifications for S.A.E. Steels. They are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

CHEMICAL COMPOSITION IN PERCENTAGE

Steel	3125	3130
Carbon	0.20-0.30	0.25-0.35
Manganese	0.50-0.80	0.50-0.80
Phosphorus	0.04 max.	0.04 max.
Sulphur	0.045 max.	0.045 max.
Nickel	1.00-1.50	1.00-1.50
Chromium	0.45-0.75	0.45-0.75

These steels may be used interchangeably with Steels 2330 and 2335 for heat-treated automotive parts requiring greater strength and toughness than provided by plain carbon steel. *They should not be used for carburizing.*

As the structure of forgings is less uniform than that of bar stock in most cases, either in the individual piece

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.15-0.25
Manganese	0.30-0.60
Phosphorus	0.04 max.
Sulphur	0.045 max.
Nickel	1.00-1.50
Chromium	0.45-0.75

Quenched at 1575 to 1625 deg. fahr. in *oil.*

The accompanying chart is intended as a guide to the proper heat-treatment of this steel and to the physical properties that may be expected of a standard 0.505 x 2-in. test-specimen machined from rolled bars *up to* 1½*-in. diameter or square.*

Brinell and scleroscope hardnesses are taken at a distance from the center equal to one-half the radius and are not to be compared with surface readings on heat-treated bars.

For bars over 1½*-in. diameter or square, this chart does not apply.*

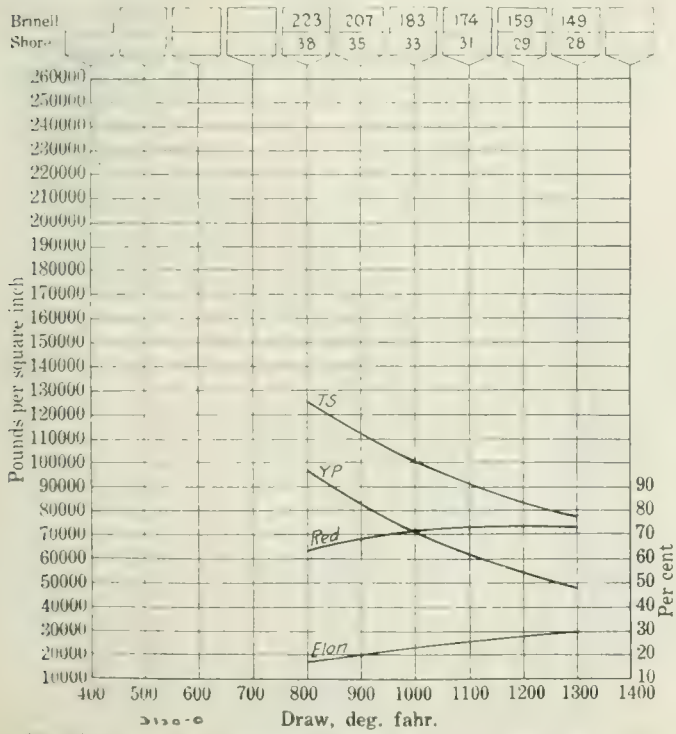


FIG. 25—PHYSICAL-PROPERTY CHART OF S.A.E. STEEL NO. 3120 QUENCHED IN OIL

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.15-0.25
Manganese	0.30-0.60
Phosphorus	0.04 max.
Sulphur	0.045 max.
Nickel	1.00-1.50
Chromium	0.45-0.75

Quenched at 1575 to 1625 deg. fahr. in *water.*

The accompanying chart is intended as a guide to the proper heat-treatment of this steel and to the physical properties that may be expected of a standard 0.505 x 2-in. test-specimen machined from rolled bars *up to* 1½*-in. diameter or square.*

Brinell and scleroscope hardnesses are taken at a distance from the center equal to one-half the radius and are not to be compared with surface readings on heat-treated bars.

For bars over 1½*-in. diameter or square, this chart does not apply.*

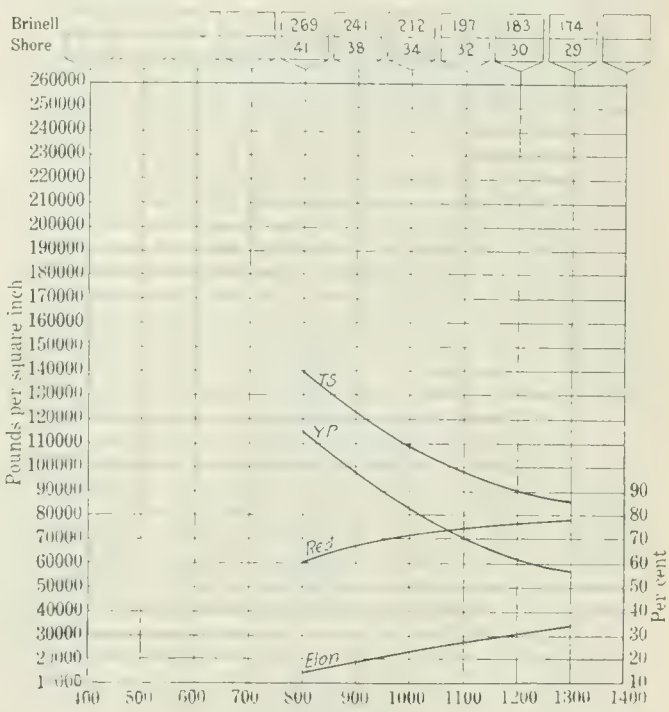


FIG. 26—PHYSICAL-PROPERTY CHART OF S.A.E. STEEL NO. 3120 QUENCHED IN WATER

or between different pieces, normalizing as in Heat-Treatment VII is recommended as the preliminary treatment for all forgings, but the desired physical properties of bar stock can be obtained generally without normalizing, as in Heat-Treatment VI.

Heat-Treatment 3125-*VI and* 3130-*VI*

1—Heat to 1500 to 1550 deg. fahr.
2—Quench
3—Draw to required hardness

Heat-Treatment 3125-*VII and* 3130-*VII*

1—Normalize at 1650 to 1750 deg. fahr.
2—Heat to 1500 to 1550 deg. fahr.
3—Quench
4—Draw to required hardness

[For physical-property charts see Figs. 27 and 28]

S.A.E. Steels 3135 *and* 3140

These Notes are not to be considered in any way a part of the standard specifications for S.A.E. Steels. They are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

CHEMICAL COMPOSITION IN PERCENTAGE

Steel	3135	3140
Carbon	0.30-0.40	0.35-0.45
Manganese	0.50-0.80	0.50-0.80
Phosphorus	0.04 max.	0.04 max.
Sulphur	0.045 max.	0.045 max.
Nickel	1.00-1.50	1.00-1.50
Chromium	0.45-0.75	0.45-0.75

These steels may also be used interchangeably with Steels 2340 and 2345 for heat-treated automotive forgings requiring greater strength and toughness than are obtainable with plain carbon steel.

As the structure of forgings is less uniform than that of bar stock in most cases, either in the individual piece or between different pieces, normalizing as in Heat-

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.25-0.35
Manganese	0.50-0.80
Phosphorus	0.04 max.
Sulphur	0.045 max.
Nickel	1.00-1.50
Chromium	0.45-0.75

Normalized at 1650 to 1750 deg. fahr.
Quenched at 1500 to 1550 deg. fahr. in *oil.*

The accompanying chart is intended as a guide to the proper heat-treatment of this steel and to the physical properties that may be expected of a standard 0.505 x 2-in. test-specimen machined from rolled bars *up to* 1½*-in. diameter or square.*

Brinell and scleroscope hardnesses are taken at a distance from the center equal to one-half the radius and are not to be compared with surface readings on heat-treated bars.

For bars over 1½*-in. diameter or square, this chart does not apply.*

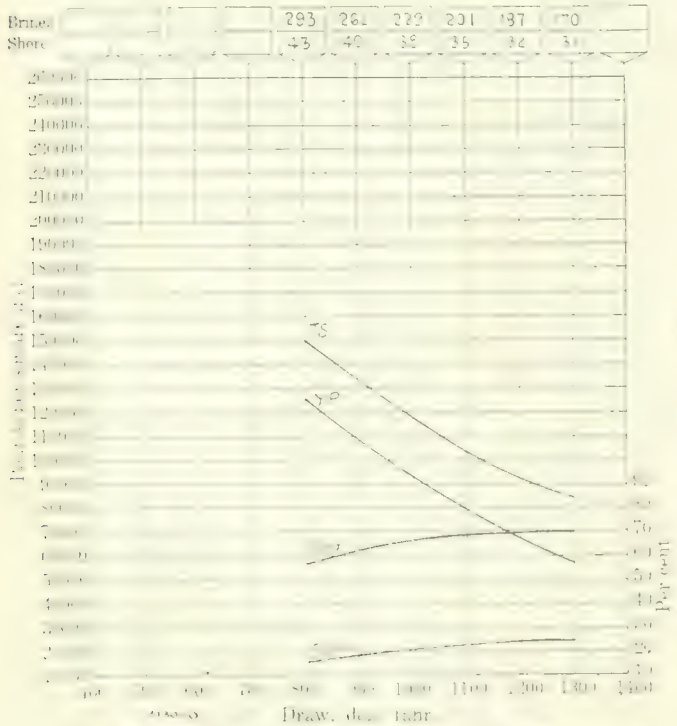



FIG. 27—PHYSICAL-PROPERTY CHART OF S.A.E. STEEL NO. 3125 QUENCHED IN OIL

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.25-0.35
Manganese	0.50-0.80
Phosphorus	0.04 max.
Sulphur	0.045 max.
Nickel	1.00-1.50
Chromium	0.45-0.75

Normalized at 1650 to 1750 deg. fahr.
Quenched at 1500 to 1550 deg. fahr. in *water*

The accompanying chart is intended as a guide to the proper heat-treatment of this steel and to the physical properties that may be expected of a standard 0.505 x 2-in. test-specimen machined from rolled bars *up to* 1½*-in. diameter or square.*

Brinell and scleroscope hardnesses are taken at a distance from the center equal to one-half the radius and are not to be compared with surface readings on heat-treated bars.

For bars over 1½*-in. diameter or square, this chart does not apply.*

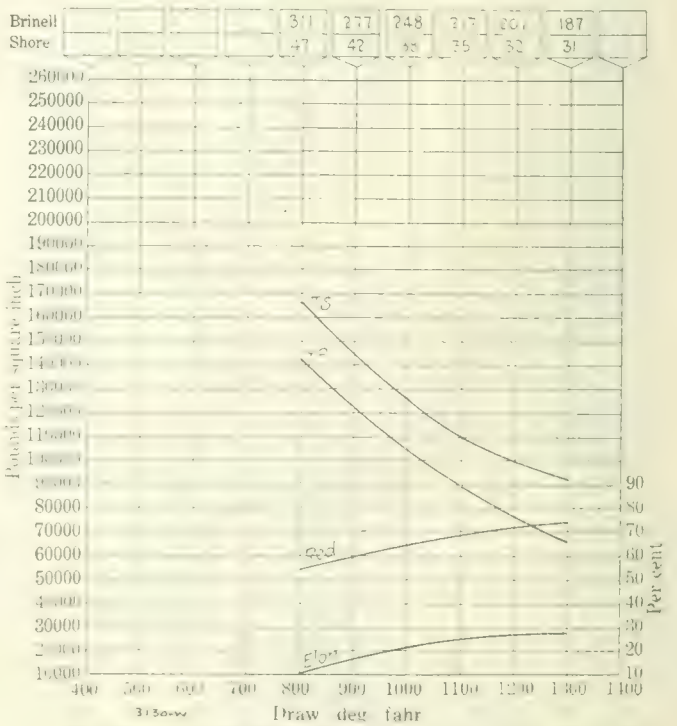


FIG. 28—PHYSICAL-PROPERTY CHART OF S.A.E. STEEL NO. 3130 QUENCHED IN WATER

Treatment VII is recommended as the preliminary treatment for all forgings, but the desired physical properties of bar stock can be obtained generally without normalizing, as in Heat-Treatment VI.

Heat-Treatment 3135-VI and 3140-VI

1—Heat to 1475 to 1525 deg. fahr.
2—Quench
3—Draw to required hardness

Heat-Treatment 3135-VII and 3140-VII

1—Normalize at 1625 to 1725 deg. fahr.
2—Heat to 1475 to 1525 deg. fahr.
3—Quench in oil
4—Draw to required hardness

[For physical property chart see Fig. 29]

S.A.E. Steels 3215 and 3220

These Notes are not to be considered in any way a part of the standard specifications for S.A.E. Steels. They are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

CHEMICAL COMPOSITION IN PERCENTAGE

Steel	3215	3220
Carbon	0.10-0.20	0.15-0.25
Manganese	0.30-0.60	0.30-0.60
Phosphorus	0.04 max.	0.04 max.
Sulphur	0.04 max.	0.04 max.
Nickel	1.50-2.00	1.50-2.00
Chromium	0.90-1.25	0.90-1.25

These steels are intended primarily for case-hardened parts that require a greater strength of core than is obtainable in Steels 3115 and 3120. They can also be used for structural parts after suitable heat-treatment. Their higher chromium content, which causes deeper penetration of the effect of heat-treatment, makes them more

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.35-0.45
Manganese	0.50-0.80
Phosphorus	0.04 max.
Sulphur	0.045 max.
Nickel	1.00-1.50
Chromium	0.45-0.75

Normalized at 1600 to 1700 deg. fahr.
Quenched at 1475 to 1525 deg. fahr. in *oil.*

The accompanying chart is intended as a guide to the proper heat-treatment of this steel and to the physical properties that may be expected of a standard 0.505 x 2-in. test-specimen machined from rolled bars *up to* 1½-*in. diameter or square.*

Brinell and scleroscope hardnesses are taken at a distance from the center equal to one-half the radius and are not to be compared with surface readings on heat-treated bars.

For bars over 1½-*in. diameter or square, this chart does not apply.*

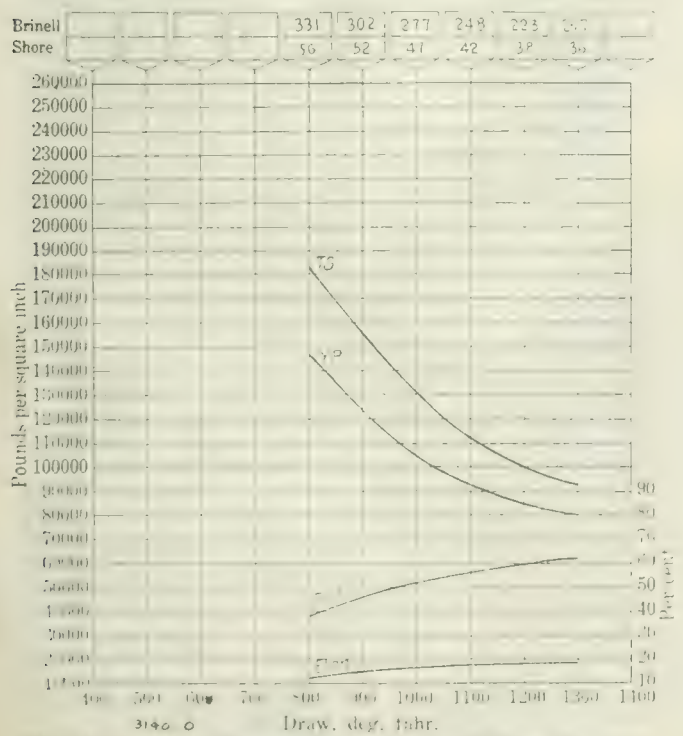


Fig. 29—Physical-Property Chart of S.A.E. Steel No. 3140 Quenched in Oil

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.15-0.25
Manganese	0.30-0.60
Phosphorus	0.04 max.
Sulphur	0.04 max.
Nickel	1.50-2.00
Chromium	0.90-1.25

Normalized at 1625 to 1725 deg. fahr.
Quenched at 1550 to 1600 deg. fahr. in *oil.*

The accompanying chart is intended as a guide to the proper heat-treatment of this steel and to the physical properties that may be expected of a standard 0.505 x 2-in. test-specimen machined from rolled bars *up to* 1½-*in. diameter or square.*

Brinell and scleroscope hardnesses are taken at a distance from the center equal to one-half the radius and are not to be compared with surface readings on heat-treated bars.

For bars over 1½-*in. diameter or square, this chart does not apply.*

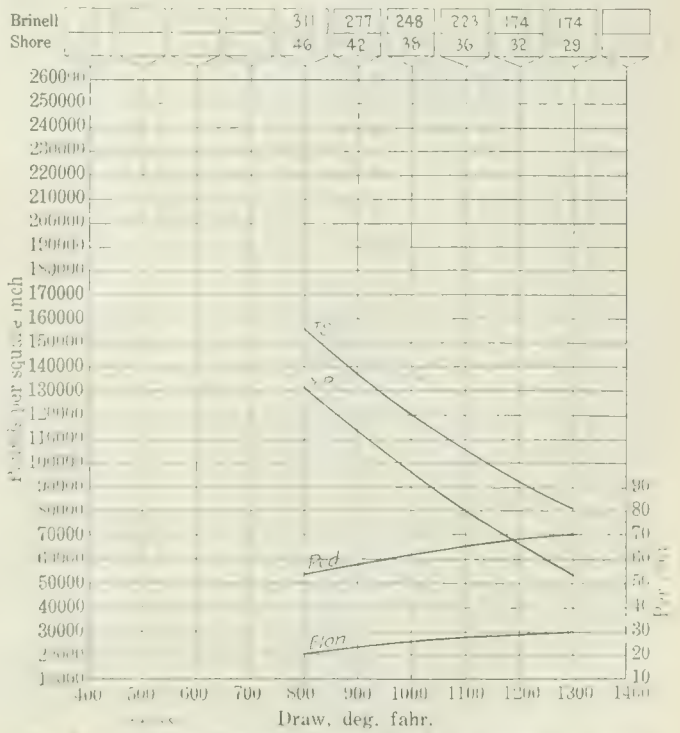


Fig. 30—Physical-Property Chart of S.A.E. Steel No. 3220 Quenched in Oil

suitable for use in heavy sections over 1½-in diameter than Steels 3115 and 3120.

Carburized parts made from these steels may be subjected to Heat-Treatment II when hardness only is required and distortion is not important. When maximum hardness of the case and maximum refinement of both the case and the core are desired, distortion again being unimportant, Heat-Treatment III should be used. When hardness, refinement of the core and least possible distortion are required, Heat-Treatment IV should be used. When refinement of both the case and the core are desired, distortion not being important, Heat-Treatment V should be used.

Steel 3220 is not recommended for case-hardening except for massive parts because of the sacrifice to ductility and support of the core resulting from the higher carbon. Subsequent to carbonizing, great care must be exercised in treatments to minimize the brittleness of the core.

When these steels are used for gears for which a high degree of accuracy and considerable strength are required, it is recommended that the carburizing operation be preceded by normalizing at 1650 to 1750 deg. fahr., which will improve the structure and tend to reduce the distortion caused by subsequent treatments.

Heat-Treatment 3215-*II and* 3220-*II*

1—Carburize at 1625 to 1675 deg. fahr.
2—Quench from box in oil
3—Reheat to 1325 to 1425 deg. fahr.
4—Quench in oil
5—Draw at 250 to 500 deg. fahr. is recommended

Heat-Treatment 3215-*III and* 3220-*III*

1—Carburize at 1625 to 1675 deg. fahr.
2—Quench from box in oil
3—Reheat to 1525 to 1575 deg. fahr.
4—Quench in oil
5—Reheat to 1375 to 1425 deg. fahr.
6—Quench in oil.
7—Draw at 250 to 500 deg. fahr. is recommended

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.15-0.25
Manganese	0.30-0.60
Phosphorus	0.04 max.
Sulphur	0.04 max.
Nickel	1.50-2.00
Chromium	0.90-1.25

Normalized at 1625 to 1725 deg. fahr.
Quenched at 1550 to 1600 deg. fahr. in *water.*

The accompanying chart is intended as a guide to the proper heat-treatment of this steel and to the physical properties that may be expected of a standard 0.505 x 2-in. test-specimen machined from rolled bars *up to* 1½-*in. diameter or square.*

Brinell and scleroscope hardnesses are taken at a distance from the center equal to one-half the radius and are not to be compared with surface readings on heat-treated bars.

For bars over 1½-*in. diameter or square, this chart does not apply.*

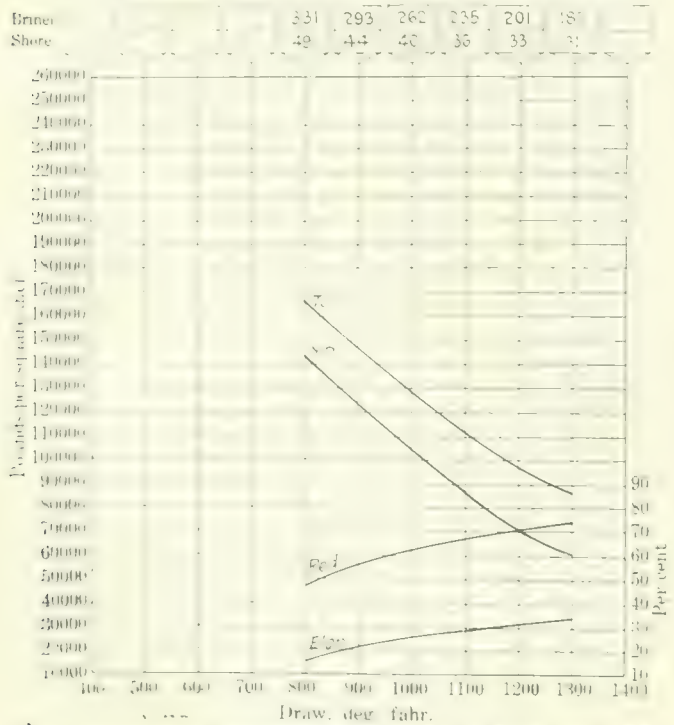


FIG. 31—PHYSICAL-PROPERTY CHART OF S.A.E. STEEL NO. 3220 QUENCHED IN WATER

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.25-0.35
Manganese	0.30-0.60
Phosphorus	0.04 max.
Sulphur	0.04 max.
Nickel	1.50-2.00
Chromium	0.90-1.25

Normalized at 1625 to 1725 deg. fahr.
Quenched at 1500 to 1550 deg. fahr. in *oil.*

The accompanying chart is intended as a guide to the proper heat-treatment of this steel and to the physical properties that may be expected of a standard 0.505 x 2-in. test-specimen machined from rolled bars *up to* 1½-*in. diameter or square.*

Brinell and scleroscope hardnesses are taken at a distance from the center equal to one-half the radius and are not to be compared with surface readings on heat-treated bars.

For bars over 1½-*in. diameter or square, this chart does not apply.*

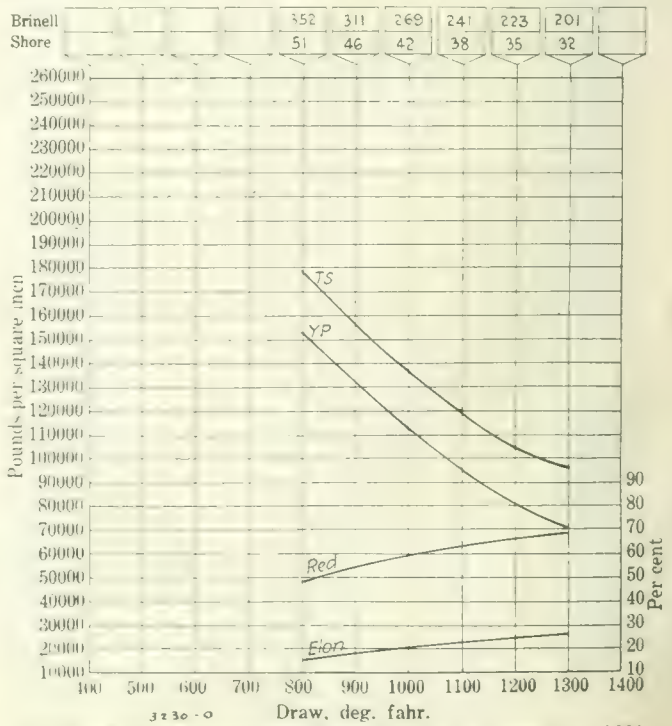


FIG. 32—PHYSICAL PROPERTY CHART OF S.A.E. STEEL NO. 3230 QUENCHED IN OIL

Heat-Treatment 3215-*IV and* 3220-*IV*

1—Carburize at 1625 to 1675 deg. fahr.
2—Cool in box
3—Reheat to 1375 to 1425 deg. fahr.
4—Quench in oil
5—Draw at 250 to 500 deg. fahr. is recommended

Heat-Treatment 3215-*V and* 3220-*V*

1—Carburize at 1625 to 1675 deg. fahr.
2—Cool in box
3—Reheat to 1525 to 1575 deg. fahr.
4—Quench in oil
5—Reheat to 1375 to 1425 deg. fahr.
6—Quench in oil
7—Draw at 250 to 500 deg. fahr. is recommended

As the structure of forgings is less uniform than that of bar stock in most cases, either in the individual piece or between different pieces, normalizing as in Heat-Treatment VII is recommended as the preliminary treatment for all forgings, but the desired physical properties of bar stock can be obtained generally without normalizing, as in Heat-Treatment VI.

Heat-Treatment 3220-*VI*

1—Heat to 1525 to 1575 deg. fahr.
2—Quench
3—Draw to required hardness

Heat-Treatment 3220-*VII*

1—Normalize at 1625 to 1725 deg. fahr.
2—Heat to 1525 to 1575 deg. fahr.
3—Quench
4—Draw to required hardness

[For physical-property charts see Figs. 30 and 31]

S.A.E. Steel 3230

These Notes are not to be considered in any way a part of the standard specifications for S.A.E. Steels. They are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.25-0.35
Manganese	0.30-0.60
Phosphorus	0.04 max.
Sulphur	0.04 max.
Nickel	1.50-2.00
Chromium	0.90-1.25

This steel is intended for heat-treated, machined and forged parts that are to be subjected to severe service conditions that demand higher physical properties than are obtainable with Steels 2330, 2335, 3125 or 3130. This steel also responds to heat-treatment more sharply and uniformly in large sections over 1½ in. in diameter than Steels 2330, 2335, 3125 or 3130.

Heat-Treatment 3230-*VI*

1—Heat to 1500 to 1550 deg. fahr.
2—Quench in oil
3—Draw to required hardness

Heat-Treatment 3230-*VII*

1—Normalize at 1625 to 1725 deg. fahr.
2—Heat to 1500 to 1550 deg. fahr.
3—Quench in oil
4—Draw to required hardness

As the structure of forgings is less uniform than that of bar stock in most cases, either in the individual piece or between different pieces, normalizing as in Heat-Treatment VII is recommended as the preliminary treatment for all forgings, but the desired physical properties of bar stock can be obtained generally without normalizing, as in Heat-Treatment VI.

[For physical-property chart see Fig. 32]

S.A.E. Steel 3240

These Notes are not to be considered in any way a part of the standard specifications for S.A.E. Steels. They are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.35-0.45
Manganese	0.30-0.60
Phosphorus	0.04 max.
Sulphur	0.04 max.
Nickel	1.50-2.00
Chromium	0.90-1.25

Normalized at 1625 to 1725 deg. fahr.
Quenched at 1475 to 1525 deg. fahr. in *oil.*

The accompanying chart is intended as a guide to the proper heat-treatment of this steel and to the physical properties that may be expected of a standard 0.505 x 2-in. test-specimen machined from rolled bars *up to* 1½*-in. diameter or square.*

Brinell and scleroscope hardnesses are taken at a distance from the center equal to one-half the radius and are not to be compared with surface readings on heat-treated bars.

For bars over 1½*-in. diameter or square, this chart does not apply.*

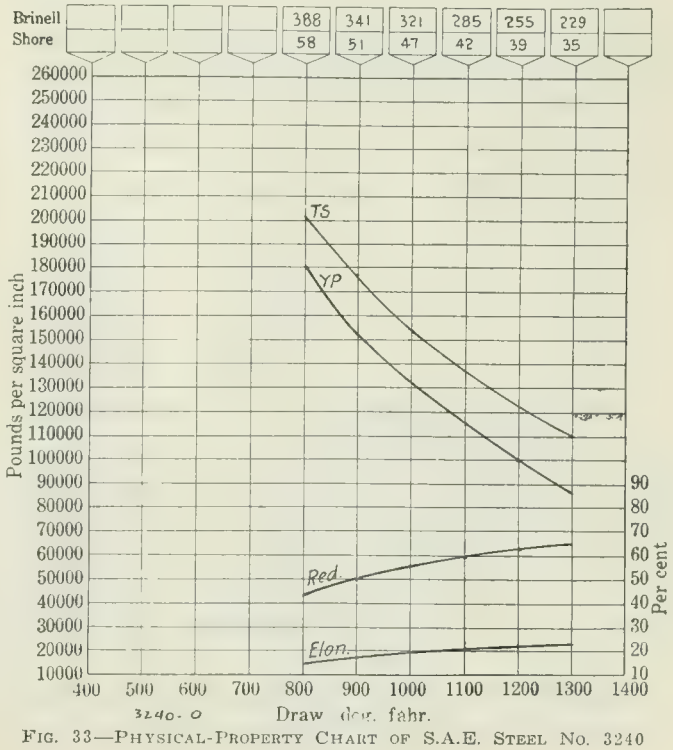


FIG. 33—PHYSICAL-PROPERTY CHART OF S.A.E. STEEL NO. 3240 QUENCHED IN OIL

This steel is intended for heat-treated forgings and machined parts that are to be subjected to service conditions demanding greater strength than is obtainable with Steels 2340, 2345, 3135 or 3140. It is also more suitable for large sections of over 1½-in. diameter than any of those steels because of the greater penetration of the effect of heat-treatment resulting from the increased chromium-content. This steel is not recommended for gears.

As the structure of forgings is less uniform than that of bar stock in most cases, either in the individual piece or between different pieces, normalizing as in Heat-Treatment VII is recommended as the preliminary treatment for all forgings, but the desired physical properties of bar stock can be obtained generally without normalizing, as in Heat-Treatment VI.

Heat-Treatment 3240-*VI*
1—Heat to 1475 to 1525 deg. fahr.
2—Quench in oil
3—Draw to required hardness

Heat-Treatment 3240-*VII*
1—Normalize at 1625 to 1725 deg. fahr.
2—Reheat to 1475 to 1525 deg. fahr.
3—Quench in oil
4—Draw to required hardness

For parts that are to be machined after forging and before treatment, Heat-Treatment VIII is recommended.

Heat-Treatment 3240-*VIII*
1—Normalize at 1625 to 1725 deg. fahr.
2—Reheat to 1250 to 1300 deg. fahr.
3—Cool slowly
4—Machine
5—Reheat to 1450 to 1500 deg. fahr
6—Quench in oil
7—Draw to required hardness

[For physical-property chart see Fig. 33]

S.A.E. Steels 3245 *and* 3250

These Notes are not to be considered in any way a part of the standard specifications for S.A.E. Steels. They are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

CHEMICAL COMPOSITION IN PERCENTAGE

Steel	3245	3250
Carbon	0.40-0.50	0.45-0.55
Manganese	0.30-0.60	0.30-0.60
Phosphorus	0.04 max.	0.04 max.
Sulphur	0.04 max.	0.04 max.
Nickel	1.50-2.00	1.50-2.00
Chromium	0.90-1.25	0.90-1.25

These steels are intended primarily for oil-hardened parts, machined or forged, that require very high physical properties. The deep penetration of the effect of heat-treatment makes them desirable steels for use in heavy sections of over 1½-in. diameter that are to be subjected to severe dynamic stresses in service.

S.A.E. Steel 3245 is specified in response to the request of the gear manufacturers, but is not reocommended in the lower carbon ranges for use in gears.

As the structure of forgings is less uniform than that of bar stock in most cases, either in the individual piece or between different pieces, normalizing as in Heat-Treatment VII is recommended as the preliminary treatment for all forgings, but the desired physical properties of bar stock can be obtained generally without normalizing, as in Heat-Treatment VI.

Heat-Treatment 3245-*VI and* 3250-*VI*
1—Heat to 1425 to 1475 deg. fahr.
2—Quench in oil
3—Draw to required hardness

Heat-Treatment 3245-*VII and* 3250-*VII*
1—Normalize at 1600 to 1700 deg. fahr.
2—Reheat to 1425 to 1475 deg. fahr.
3—Quench in oil
4—Draw to required hardness

For parts, such as gears, that are to be machined after forging and before treatment, Heat-Treatment VIII is recommended.

Heat-Treatment 3245-*VIII and* 3250-*VIII*
1—Normalize at 1600 to 1700 deg. fahr.
2—Reheat to 1250 to 1300 deg. fahr.
3—Cool slowly
4—Machine
5—Reheat to 1400 to 1450 deg. fahr.
6—Quench in oil
7—Draw to required hardness

[For physical-property chart see Fig. 34]

S.A.E. Steel 3312

These Notes are not to be considered in any way a part of the standard specifications for S.A.E. Steels. They are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.17 max.
Manganese	0.30-0.60
Phosphorus	0.04 max.
Sulphur	0.04 max.
Nickel	3.25-3.75
Chromium	1.25-1.75

Heat-Treatment 3312-*II*
1—Carburize at temperature from 1600 to 1650 deg. fahr.
2—Quench from box in oil
3—Reheat to 1375 to 1425 deg. fahr.
4—Quench in oil
5—Draw to 250 to 500 deg. fahr. is recommended

Heat-Treatment 3312-*III*
1—Carburize at 1600 to 1650 deg. fahr.
2—Quench from box in oil
3—Reheat to 1475 to 1525 deg. fahr.
4—Quench in oil
5—Reheat to 1375 to 1425 deg. fahr.
6—Quench in oil
7—Draw at 250 to 500 deg. fahr. is recommended

Heat-Treatment 3312-*IV*
1—Carburize at 1600 to 1650 deg. fahr.
2—Cool in box
3—Reheat to 1400 to 1450 deg. fahr.
4—Quench in oil
5—Draw at 250 to 500 deg. fahr. is recommended

Heat-Treatment 3312-*V*
1—Carburize at 1600 to 1650 deg. fahr.
2—Cool in box
3—Reheat to 1525 to 1575 deg. fahr.
4—Quench in oil
5—Reheat to 1375 to 1425 deg. fahr.
6—Quench in oil
7—Draw at 250 to 500 deg. fahr. is recommended

This steel is intended primarily for case-hardening when a core possessing very high strength and toughness is desired.

Carburized parts made from this steel may be subjected to Heat-Treatment II when hardness only is required and distortion is not important. When maximum hardness of the case and refinement of both the case and the core are desired, distortion again being unimportant, Heat-Treatment III should be used. When hardness, refinement of the core and the least possible distortion are required, Heat-Treatment IV should be used. When refinement of both the case and the core is desired, distortion not being important, Heat-Treatment V should be used.

When this steel is used for gears for which a high degree of accuracy and strength is required, it is recommended that the carburizing operation be preceded by a normalizing treatment or a quench and draw operation, which will improve the structure and machineability and tend to reduce the distortion caused by subsequent treatments.

S.A.E. Steel 3325

These Notes are not to be considered in any way a part of the standard specifications for S.A.E. Steels. They are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.20-0.30
Manganese	0.30-0.60
Phosphorus	0.04 max.
Sulphur	0.04 max.
Nickel	3.25-3.75
Chromium	1.25-1.75

This steel can be used interchangeably with Steel 3230 for heat-treated, machined and forged parts that must

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.45-0.55
Manganese	0.30-0.60
Phosphorus	0.04 max.
Sulphur	0.04 max.
Nickel	1.50-2.00
Chromium	0.90-1.25

Normalized at 1600 to 1700 deg. fahr.
Quenched at 1425 to 1475 deg. fahr. in *oil.*

The accompanying chart is intended as a guide to the proper heat-treatment of this steel and to the physical properties that may be expected of a standard 0.505 x 2-in. test-specimen machined from rolled bars *up to* 1½-*in. diameter or square.*

Brinell and scleroscope hardnesses are taken at a distance from the center equal to one-half the radius and are not to be compared with surface readings on heat-treated bars.

For bars over 1½-*in. diameter or square, this chart does not apply.*

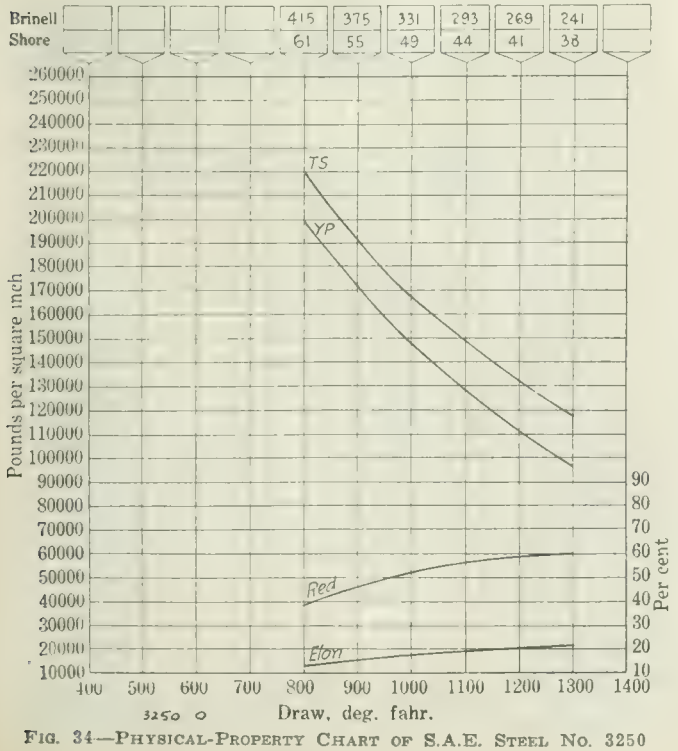


FIG. 34—PHYSICAL-PROPERTY CHART OF S.A.E. STEEL NO. 3250 QUENCHED IN OIL

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.20-0.30
Manganese	0.30-0.60
Phosphorus	0.04 max.
Sulphur	0.04 max.
Nickel	3.25-3.75
Chromium	1.25-1.75

Normalized at 1600 to 1700 deg. fahr.
Quenched at 1475 to 1525 deg. fahr. in *oil.*

The accompanying chart is intended as a guide to the proper heat-treatment of this steel and to the physical properties that may be expected of a standard 0.505 x 2-in. test-specimen machined from rolled bars *up to* 1½-*in. diameter or square.*

Brinell and scleroscope hardnesses are taken at a distance from the center equal to one-half the radius and are not to be compared with surface readings on heat-treated bars.

For bars over 1½-*in. diameter or square, this chart does not apply.*

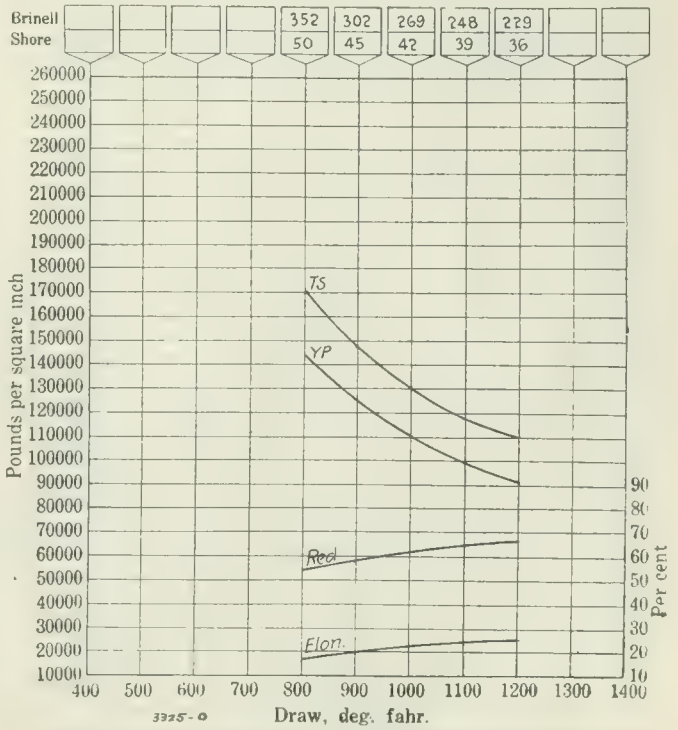


FIG. 35—PHYSICAL-PROPERTY CHART OF S.A.E. STEEL NO 3325 QUENCHED IN OIL

possess very high physical properties and be capable of resisting severe dynamic stresses in service.

As the structure of forgings is less uniform than that of bar stock in most cases, either in the individual piece or between different pieces, normalizing as in Heat-Treatment VII is recommended as the preliminary treatment for all forgings, but the desired physical properties of bar stock can be obtained generally without normalizing, as in Heat-Treatment VI.

Heat-Treatment 3325-*VI*

1—Heat to 1475 to 1525 deg. fahr.
2—Quench in oil
3—Draw to required hardness

Heat-Treatment 3325-*VII*

1—Normalize at 1600 to 1700 deg. fahr.
2—Reheat to 1475 to 1525 deg. fahr.
3—Quench in oil
4—Draw to required hardness

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.30-0.40
Manganese	0.30-0.60
Phosphorus	0.04 max.
Sulphur	0.04 max.
Nickel	3.25-3.75
Chromium	1.25-1.75

Normalized at 1600 to 1700 deg. fahr.
Quenched at 1425 to 1475 deg. fahr. in *oil.*

The accompanying chart is intended as a guide to the proper heat-treatment of this steel and to the physical properties that may be expected of a standard 0.505 x 2-in. test-specimen machined from rolled bars *up to* 1½-*in. diameter or square.*

Brinell and scleroscope hardnesses are taken at a distance from the center equal to one-half the radius and are not to be compared with surface readings on heat-treated bars.

For bars over 1½-*in. diameter or square, this chart does not apply.*

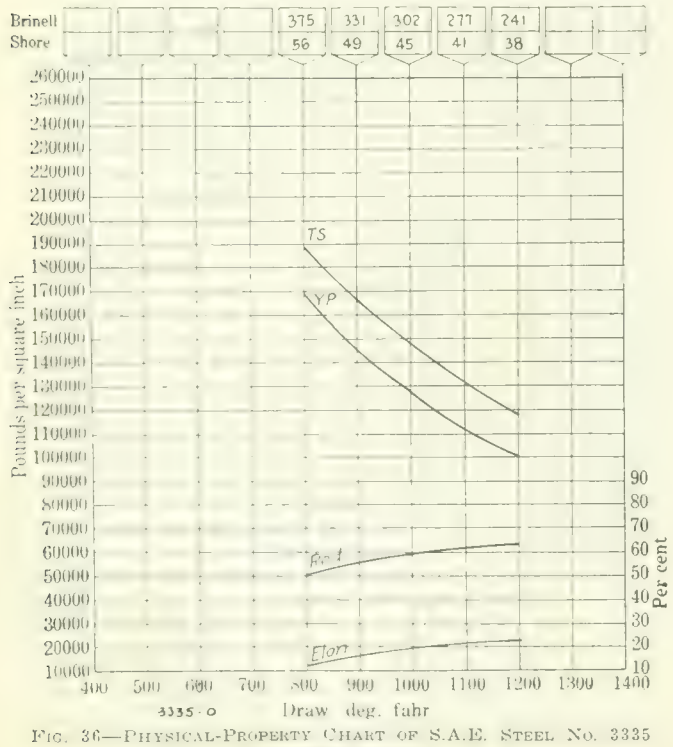


FIG. 36—PHYSICAL-PROPERTY CHART OF S.A.E. STEEL NO. 3335 QUENCHED IN OIL

For parts that are to be machined after forging and before treatment, Heat-Treatment VIII is recommended.

Heat-Treatment 3325-*VIII*

1—Normalize at 1600 to 1700 deg. fahr.
2—Reheat to 1200 to 1250 deg. fahr.
3—Cool slowly in furnace
4—Machine
5—Reheat to 1475 to 1525 deg. fahr.
6—Quench in oil
7—Draw to required hardness

[For physical-property chart see Fig. 35]

S.A.E. Steels 3335 *and* 3340

These Notes are not to be considered in any way a part of the standard specifications for S.A.E. Steels. They are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

CHEMICAL COMPOSITION IN PERCENTAGE

Steels	3335	3340
Carbon	0.30-0.40	0.35-0.45
Manganese	0.30-0.60	0.30-0.60
Phosphorus	0.04 max.	0.04 max.
Sulphur	0.04 max.	0.04 max
Nickel	3.25-3.75	3.25-3.75
Chromium	1.25-1.75	1.25-1.75

These steels may be used interchangeably with Steel 3240 for such heat-treated parts, either machined or forged, as require exceptionally high physical properties and must be capable of resisting severe dynamic stresses in service.

By reason of the high alloy-content of these steels and their sensitiveness to heat-treatment, it is desirable to precede all heat-treatment operations by a normalizing treatment, as recommended in Heat-Treatment VII.

Heat-Treatment 3335-*VII and* 3340-*VII*

1—Normalize at 1600 to 1700 deg. fahr.
2—Reheat to 1425 to 1475 deg. fahr.
3—Quench in oil
4—Draw to required hardness

For parts, such as gears, that are to be machined after forging and before treatment, Heat-Treatment VIII is recommended.

Heat-Treatment 3335-*VIII and* 3340-*VIII*

1—Normalize at 1600 to 1700 deg. fahr.
2—Reheat to 1200 to 1250 deg. fahr.
3—Cool slowly in furnace
4—Machine
5—Reheat to 1425 to 1475 deg. fahr.
6—Quench in oil
7—Draw to required hardness

[For physical-property chart see Fig. 36]

S.A.E. Steel 3415

These Notes are not to be considered in any way a part of the standard specifications for S.A.E. Steels. They are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.10-0.20
Manganese	0.45-0.75
Phosphorus	0.04 max.
Sulphur	0.04 max.
Nickel	2.75-3.25
Chromium	0.60-0.95

This steel is intended primarily for case-hardening when a core possessing very high strength and toughness is desired.

When this steel is used for gears for which a high degree of accuracy and strength is required, it is recommended that the carburizing operation be preceded by a normalizing or a quench and draw operation, which will improve the structure and machineability and tend to reduce the distortion caused by subsequent treatments.

Case-hardened parts made from this steel may be subjected to Heat-Treatment II when maximum hardness only is required and distortion is not important. When maximum hardness of the case and maximum refinement of both the case and the core are desired, distortion again being unimportant, Heat-Treatment III should be used. When hardness, refinement of the case and least possible distortion are required, Heat-Treatment IV should be used. When refinement of both the case and the core are desired, distortion not being important, Heat-Treatment V should be used.

Heat-Treatment 3415-*II*
1—Carburize at 1600 to 1650 deg. fahr.
2—Quench from box in oil
3—Reheat to 1375 to 1425 deg. fahr.
4—Quench in oil
5—Draw at 250 to 500 deg. fahr. is recommended

Heat-Treatment 3415-*III*
1—Carburize at 1600 to 1650 deg. fahr.
2—Quench from box in oil
3—Reheat to 1500 to 1550 deg. fahr.
4—Quench in oil
5—Reheat to 1375 to 1425 deg. fahr.
6—Quench in oil
7—Draw at 250 to 500 deg. fahr. is recommended

Heat-Treatment 3415-*IV*
1—Carburize at 1600 to 1650 deg. fahr.
2—Cool in box
3—Reheat to 1400 to 1450 deg. fahr.
4—Quench in oil
5—Draw at 250 to 500 deg. fahr. is recommended

Heat-Treatment 3415-*V*
1—Carburize at 1600 to 1650 deg. fahr.
2—Cool in box
3—Reheat to 1500 to 1550 deg. fahr.
4—Quench in oil
5—Reheat to 1375 to 1425 deg. fahr.
6—Quench in oil
7—Draw at 250 to 500 deg. fahr. is recommended

S.A.E. Steel 3435

These Notes are not to be considered in any way a part of the standard specifications for S.A.E. Steels. They are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.30-0.40
Manganese	0.45-0.75
Phosphorus	0.04 max.
Sulphur	0.04 max.
Nickel	2.75-3.25
Chromium	0.60-0.95

This steel is intended for heat-treated machined and forged parts that are to be subjected to severe service conditions requiring higher physical properties than are obtainable with Steels 2330, 2335, 3125 or 3130. It also responds to heat-treatment more sharply and uniformly in large sections of over 1½-in. diameter than the steels mentioned.

By reason of the high alloy-content of this steel and its sensitiveness to heat-treatment, it is desirable to precede all heat-treatment operations by a normalizing treatment as recommended in Heat-Treatment VII.

Heat-Treatment 3435-*VII*
1—Normalize at 1550 to 1650 deg. fahr.
2—Heat to 1425 to 1475 deg. fahr.
3—Quench in oil
4—Draw to required hardness

Heat-Treatment 3435-*VIII*
1—Normalize at 1550 to 1650 deg. fahr.
2—Heat to 1250 to 1300 deg. fahr.
3—Cool slowly in furnace
4—Machine
5—Heat to 1425 to 1475 deg. fahr.
6—Quench in oil
7—Draw to required hardness

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.30-0.40
Manganese	0.45-0.75
Phosphorus	0.04 max.
Sulphur	0.04 max.
Nickel	2.75-3.75
Chromium	0.60-0.95

Normalized at 1550 to 1650 deg. fahr.
Quenched at 1425 to 1475 deg. fahr. in *oil.*

The accompanying chart is intended as a guide to the proper heat-treatment of this steel and to the physical properties that may be expected of a standard 0.505 x 2-in. test-specimen machined from rolled bars *up to 1½-in. diameter or square.*

Brinell and scleroscope hardnesses are taken at a distance from the center equal to one-half the radius and are not to be compared with surface readings on heat-treated bars.

For bars over 1½-in. diameter or square, this chart does not apply.

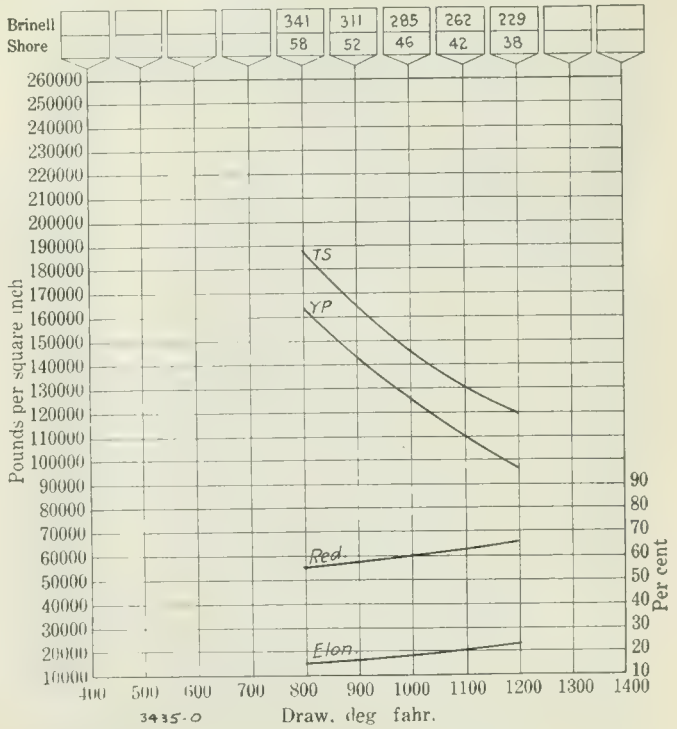


FIG. 37—PHYSICAL-PROPERTY CHART OF S.A.E. STEEL NO. 3435 QUENCHED IN OIL

For parts that are to be machined after forging and before treatment, Heat-Treatment VIII is recommended.

[For physical-property chart see Fig. 37]

S.A.E. Steel 3450

These Notes are not to be considered in any way a part of the standard specifications for S.A.E. Steels. They are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.45-0.55
Manganese	0.45-0.75
Phosphorus	0.04 max.
Sulphur	0.04 max.
Nickel	2.75-3.25
Chromium	0.60-0.95

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.45-0.55
Manganese	0.45-0.75
Phosphorus	0.04 max.
Sulphur	0.04 max.
Nickel	2.75-3.25
Chromium	0.60-0.95

Normalized at 1550 to 1650 deg. fahr.
Quenched at 1400 to 1450 deg. fahr. in *oil.*

The accompanying chart is intended as a guide to the proper heat-treatment of this steel and to the physical properties that may be expected of a standard 0.505 x 2-in. test-specimen machined from rolled bars *up to* 1½*-in. diameter or square.*

Brinell and scleroscope hardnesses are taken at a distance from the center equal to one-half the radius and are not to be compared with surface readings on heat-treated bars.

For bars over 1½*-in. diameter or square, this chart does not apply.*

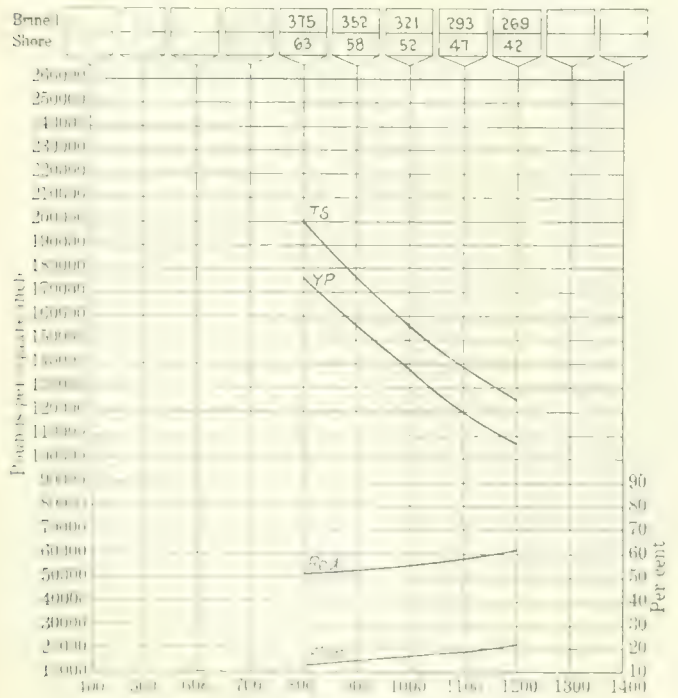


Fig. 28—Effect of Drawing Temperature on Physical Properties of S.A.E. Steel No. 3450 Quenched in Oil

This steel may be used interchangably with Steels 3240 and 3340 for such heat-treated parts, either machined or forged, as require exceptionally high physical properties and must be capable of resisting severe dynamic stresses in service.

By reason of the high alloy-content of this steel and its sensitiveness to heat-treatment, it is desirable to precede all heat-treatment operations by a normalizing treatment, as recommended in Heat-Treatment VII.

Heat-Treatment 3450-*VII*
1—Normalize at 1550 to 1650 deg. fahr.
2—Reheat to 1400 to 1450 deg. fahr.
3—Quench in oil
4—Draw to required hardness

For parts, such as gears, that are to be machined after forging and before treatment, Heat-Treatment VIII is recommended.

Heat-Treatment 3450-*VIII*
1—Normalize at 1550 to 1650 deg. fahr.
2—Reheat to 1250 to 1300 deg. fahr.
3—Cool slowly in furnace
4—Machine
5—Reheat to 1400 to 1450 deg. fahr.
6—Quench in oil
7—Draw to required hardness

[For physical property chart see Fig. 38]

S.A.E. Steel 5120

These Notes are not to be considered in any way a part of the standard specifications for S.A.E. Steels. They are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.15-0.25
Manganese	0.30-0.60
Phosphorus	0.04 max.
Sulphur	0.045 max.
Chromium	0.60-0.90

Heat-Treatment 5120-*II*
1—Carburize at 1650 to 1700 deg. fahr.
2—Quench from box in oil
3—Reheat to 1425 to 1475 deg. fahr.
5—Draw to 250 to 500 deg. fahr. is recommended

Heat-Treatment 5120-*III*
1—Carburize at 1650 to 1700 deg. fahr.
2—Quench from box in oil
3—Reheat to 1600 to 1650 deg. fahr.
4—Quench in oil
5—Reheat to 1425 to 1475 deg. fahr.
6—Quench
7—Draw at 250 to 500 deg. fahr. is recommended

Heat-Treatment 5120-*IV*
1—Carburize at 1650 to 1700 deg. fahr.
2—Cool in box
3—Reheat to 1525 to 1575 deg. fahr.
4—Quench
5—Draw at 250 to 500 deg. fahr. is recommended

Heat-Treatment 5120-*V*
1—Carburize at 1650 to 1700 deg. fahr.
2—Cool in box
3—Reheat to 1600 to 1650 deg. fahr.
4—Quench in oil
4—Quench
5—Reheat to 1425 to 1475 deg. fahr.
6—Quench
7—Draw at 250 to 500 deg. fahr. is recommended

This steel is intended primarily for case-hardening.

For structural purposes the chromium-content of this steel gives a deeper penetration of the effect of heat-treatment than can be attained in a plain carbon-steel having a similar carbon-content, and the physical properties are similar to those of Steels 2320 and 3120.

When this steel is to be case-hardened for use in gears for which a high degree of accuracy and strength is required, it is recommended that the carburizing operation be preceded by normalizing at 1600 to 1700 deg. fahr., which will improve the structure and tend to reduce the distortion caused by subsequent treatments.

Case-hardened parts made from this steel may be subjected to Heat-Treatment II when maximum hardness of the case only is required and distortion is not important. When maximum hardness and maximum refinement of both the case and the core are desired, distortion again being unimportant, Heat-Treatment III should be used. When hardness, refinement of the case and the least possible distortion are required, Heat-Treatment IV should be used. When refinement of both the case and the core is desired, distortion not being important, Heat-Treatment V should be used.

S.A.E. Steel 5140

These Notes are not to be considered in any way a part of the standard specifications for S.A.E. Steels. They are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.35-0.45
Manganese	0.50-0.80
Phosphorus	0.04 max.
Sulphur	0.045 max.
Chromium	0.80-1.10

This steel may be used interchangeably with Steels 2340 and 3140 for heat-treated automotive forgings requiring greater strength and toughness than are obtainable in plain carbon-steels. It also has a wider heat-treating range.

As the structure of forgings is less uniform than that of bar stock in most cases, either in the individual piece or between different pieces, normalizing as in Heat-Treatment VII is recommended as the preliminary treatment for all forgings, but the desired physical properties of bar stock can be obtained generally without normalizing, as in Heat-Treatment VI.

Heat-Treatment 5140-*VI*

1—Heat to 1500 to 1600 deg. fahr.
2—Quench in oil
3—Draw to required hardness

Heat-Treatment 5140-*VII*

1—Normalize at 1625 to 1725 deg. fahr.
2—Reheat to 1500 to 1600 deg. fahr.
3—Quench in oil
4—Draw to required hardness

For parts that are to be machined after forging and before treatment, Heat-Treatment VIII is recommended.

With regard to parts that are to be machined in automatics the temperature for operation 2 should not exceed 1290 deg. fahr., although for parts that are to be machined in lathes, the temperature may range as high as 1400 deg. fahr.

Heat-Treatment 5140-*VIII*

1—Normalize at 1625 to 1725 deg. fahr.
2—Reheat to 1250 to 1350 deg. fahr.
3—Cool slowly in furnace
4—Machine
5—Reheat to 1500 to 1600 deg. fahr.
6—Quench in oil
7—Draw to required hardness

S.A.E. Steel 5150

These Notes are not to be considered in any way a part of the standard specifications for S.A.E. Steels. They are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.45-0.55
Manganese	0.50-0.80
Phosphorus	0.04 max.
Sulphur	0.045 max.
Chromium	0.80-1.10

This is an oil-hardening type of steel intended for heat-treated automotive forgings that require greater strength and toughness than are obtainable with plain carbon-steels or with some of the simple alloy-steels having a lower carbon-content. It also has a wider heat-treating range than the other simple alloy-steels.

As the structure of forgings is less uniform than that of bar stock in most cases, either in the individual piece or between different pieces, normalizing as in Heat-Treatment VII is recommended as the preliminary treatment for all forgings, but the desired physical properties of bar stock can be obtained generally without normalizing, as in Heat-Treatment VI.

Heat-Treatment 5150-*VI*

1—Heat to 1450 to 1550 deg. fahr.
2—Quench in oil
3—Draw to required hardness

Heat-Treatment 5150-*VII*

1—Normalize at 1600 to 1700 deg. fahr.
2—Reheat to 1450 to 1550 deg. fahr.
3—Quench in oil
4—Draw to required hardness

For parts that are to be machined after forging and before treatment, Heat-Treatment VIII is recommended.

With regard to parts that are to be machined in automatics the temperature for operation 2 should not exceed 1290 deg. fahr., although for parts that are to be machined in lathes, the temperature may range as high as 1400 deg. fahr.

Heat-Treatment 5150-*VIII*

1—Normalize at 1600 to 1700 deg. fahr.
2—Reheat to 1250 to 1350 deg. fahr.
3—Cool slowly in furnace
4—Machine
5—Reheat to 1450 to 1550 deg. fahr.
6—Quench in oil
7—Draw to required hardness

S.A.E. Steel 52100

These Notes are not to be considered in any way a part of the standard specifications for S.A.E. Steels. They are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.95-1.10
Manganese	0.20-0.50
Phosphorus	0.03 max.
Sulphur	0.03 max.
Chromium	1.20-1.50

This steel is used chiefly for the races and balls or rollers of anti-friction bearings.

The chromium and carbon-contents cause a maximum penetration of the effect of heat-treatment and develop a high degree of hardness.

For all general applications when a normalized and annealed material is to be handled, Heat-Treatment VI is recommended.

Heat-Treatment 52100-*VI*

1—Heat to 1500 to 1550 deg. fahr.
2—Quench in oil
3—Draw to required hardness

When the user forges or hot-presses parts to shape, a special treatment must precede all machining operations.

Heat-Treatment 52100 *Special*

1—Heat to 1650 to 1750 deg. fahr.
2—Cool to 1000 deg. fahr., black heat, by opening furnace
3—Reheat to 1300 to 1350 deg. fahr. and hold for at least 36 hr. or until the desired structure and machinability are obtained. Then cool slowly in furnace
4—Machine
5—Reheat to 1500 to 1550 deg. fahr.
6—Quench in oil
7—Draw to required hardness

S.A.E. Steel 6120

These Notes are not to be considered in any way a part of the standard specifications for S.A.E. Steels. They are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.15-0.25
Manganese	0.50-0.80
Phosphorus	0.04 max.
Sulphur	0.04 max.
Chromium	0.80-1.10
Vanadium	0.15 min.
	0.18 desired

This steel is intended primarily for case-hardening and can be used interchangeably with Steels 2315, 2320, 3115 and 3120 for such purpose. It can also be used for structural parts after suitable heat-treatment.

Carburized parts made from this steel may be subjected to Heat-Treatment II when hardness only is required and distortion is not important. When maximum hardness of the case and maximum refinement of both the case and the core are desired, distortion again being unimportant, Heat-Treatment III should be used. When hardness, refinement of the case and the least poossible distortion are required, Heat-Treatment IV should be used. When refinement of both the case and the core is desired, distortion not being important, Heat-Treatment V should be used.

When this steel is used for gears for which a high degree of accuracy and strength is required, it is recommended that the carburizing operation be preceded by normalizing at 1650 to 1750 deg. fahr., which will improve the structure and tend to reduce the distortion caused by subsequent treatments.

Heat-Treatment 6120-*II*

1—Carburize at 1650 to 1700 deg. fahr.
2—Quench from box in oil
3—Reheat to 1425 to 1475 deg. fahr.
4—Quench
5—Draw to 250 to 500 deg. fahr. is recommended

Heat-Treatment 6120-*III*

1—Carburize at 1650 to 1700 deg. fahr.
2—Quench from box in oil
3—Reheat to 1600 to 1650 deg. fahr.
4—Quench in oil
5—Reheat to 1425 to 1475 deg. fahr.
6—Quench
7—Draw to 250 to 500 deg. fahr. is recommended

Heat-Treatment 6120-*IV*

1—Carburize at 1650 to 1700 deg. fahr.
2—Cool in box
3—Reheat to 1525 to 1575 deg. fahr.
4—Quench
5—Draw to 250 to 500 deg. fahr. is recommended

Heat-Treatment 6120-*V*

1—Carburize at 1650 to 1700 deg. fahr.
2—Cool in box
3—Reheat to 1600 to 1650 deg. fahr.
4—Quench in oil
5—Reheat to 1425 to 1475 deg. fahr.
6—Quench
7—Draw to 250 to 500 deg. fahr. is recommended

S.A.E. Steels 6125 *and* 6130

These Notes are not to be considered in any way a part of the standard specifications for S.A.E. Steels. They are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

CHEMICAL COMPOSITION IN PERCENTAGE

Steel	6125	6130
Carbon	0.20-0.30	0.25-0.35
Manganese	0.50-0.80	0.50-0.80
Phosphorus	0.04 max	0.04 max.
Sulphur	0.04 max.	0.04 max.
Chromium	0.80-1.10	0.80-1.10
Vanadium	0.15 min.	0.15 min.
	0.18 desired	0.18 desired

This steel can be used interchangeably with Steels 2330, 2335, 3125, 3130 and 3325 for heat-treated automotive forgings requiring greater strength and toughness than are obtainable with plain carbon-steel.

As the structure of forgings is less uniform than that of bar stock in most cases, either in the individual piece or between different pieces, normalizing as in Heat-Treatment VII is recommended as the preliminary treatment for all forgings, but the desired physical properties of bar stock can be obtained generally without normalizing, as in Heat-Treatment VI.

Heat-Treatment 6125-*VI and* 6130-*VI*

1—Heat to 1575 to 1675 deg. fahr.
2—Quench
3—Draw to required hardness

Heat-Treatment 6125-*VII and* 6130-*VII*

1—Normalize at 1650 to 1750 deg. fahr.
2—Reheat to 1575 to 1675 deg. fahr.
3—Quench
4—Draw to required hardness

For forgings that are to be machined after heat-treating Heat-Treatment VII is recommended.

S.A.E. Steels 6135 *and* 6140

These Notes are not to be considered in any way a part of the standard specifications for S.A.E. Steels. They are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

CHEMICAL COMPOSITION IN PERCENTAGE

Steel	6135	6140
Carbon	0.30-0.40	0.35-0.45
Manganese	0.50-0.80	0.50-0.80
Phosphorus	0.04 max.	0.04 max.
Sulphur	0.04 max.	0.04 max.
Chromuim	0.80-1.10	0.80-1.10
Vanadium	0.15 min.	0.15 min.
	0.18 desired	0.19 desired

These steels can be used interchangeably with the nickel and nickel-chromium steels of similar carbon-content for heat-treated automotive forgings requiring greater strength, toughness and resistance to fatiguing conditions than it is possible to obtain with plain carbon-steel.

As the structure of forgings is less uniform than that of bar stock in most cases, either in the individual piece or between different pieces, normalizing as in Heat-Treatment VII is recommended as the preliminary treatment for all forgings, but the desired physical properties of bar stock can be obtained generally without normalizing, as in Heat-Treatment VI.

Heat-Treatment 6135-*VI and* 6140-*VI*
1—Heat to 1550 to 1650 deg. fahr.
2—Quench in oil
3—Draw to required hardness

For all general requirements Heat-Treatment VII is recommended.

Heat-Treatment 6135-*VII and* 6140-*VII*
1—Normalize at 1650 to 1750 deg. fahr.
2—Reheat to 1550 to 1650 deg. fahr.
3—Quench in oil
4—Draw to required hardness

For parts that are to be machined after forging and before treatment, Heat-Treatment VIII is recommended.

Heat-Treatment 6135-*VIII and* 6140-*VIII*
1—Normalize at 1650 to 1750 deg. fahr.
2—Reheat to 1250 to 1350 deg. fahr.
3—Cool slowly
4—Machine
5—Reheat to 1550 to 1650 deg. fahr.
6—Quench in oil
7—Draw to required hardness

S.A.E. Steels 6145 *and* 6150

These Notes are not to be considered in any way a part of the standard specifications for S.A.E. Steels. They are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

These steels are intended for heat-treated forgings and machined parts that are to be subjected to service conditions requiring greater strength than is obtainable with Steels 1045 and 2345 or low-chromium-nickel steels of similar carbon-content.

CHEMICAL COMPOSITION IN PERCENTAGE

Steel	6145	6150
Carbon	0.40-0.50	0.45-0.55
Manganese	0.50-0.80	0.50-0.80
Phosphorus	0.04 max.	0.04 max.
Sulphur	0.04 max.	0.04 max.
Chromium	0.80-1.10	0.80-1.10
Vanadium	0.15 min.	0.15 min.
	0.18 desired	0.19 desired

As the structure of forgings is less uniform than that of bar stock in most cases, either in the individual piece or between different pieces, normalizing as in Heat-Treatment VII is recommended as the preliminary treatment for all forgings, but the desired physical properties of bar stock can be obtained generally without normalizing, as in Heat-Treatment VI.

Heat-Treatment 6145-*VI and* 6150-*VI*
1—Heat to 1525 to 1625 deg. fahr.
2—Quench in oil
3—Draw to required hardness

Heat-Treatment 6145-*VII and* 6150-*VII*
1—Normalize at 1650 to 1750 deg. fahr.
2—Reheat to 1525 to 1625 deg. fahr.
3—Quench in oil
4—Draw to required hardness

For parts, such as gears, that are to be machined after forging and before treatment, Heat-Treatment VIII is recommended.

Heat-Treatment 6145-*VIII and* 6150-*VIII*
1—Normalize at 1650 to 1750 deg. fahr.
2—Reheat to 1250 to 1350 deg. fahr.
3—Cool slowly
4—Machine
5—Reheat to 1525 to 1625 deg. fahr.
6—Quench in oil
7—Draw to required hardness

S.A.E. Steel 6195

These Notes are not to be considered in any way a part of the standard specifications for S.A.E. Steels. They are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.90-1.05
Manganese	0.20-0.45
Phosphorus	0.03 max.
Sulphur	0.03 max.
Chromium	0.80-1.10
Vanadium	0.15 min.
	0.18 desired

Heat-Treatment 6195-*VI*
1—Heat to 1500 to 1550 deg. fahr.
2—Quench in oil
3—Draw to required hardness

Heat-Treatment 6195 *Special*
1—Heat to 1650 to 1750 deg. fahr.
2—Cool to 1000 deg. fahr., black heat, by opening furnace
3—Reheat to 1300 to 1350 deg. fahr. and hold for at least 36 hr. or until the desired structure and machinability are obtained. Then cool slowly in furnace
4—Machine
5—Reheat to 1500 to 1550 deg. fahr.
6—Quench in oil
7—Draw to required hardness

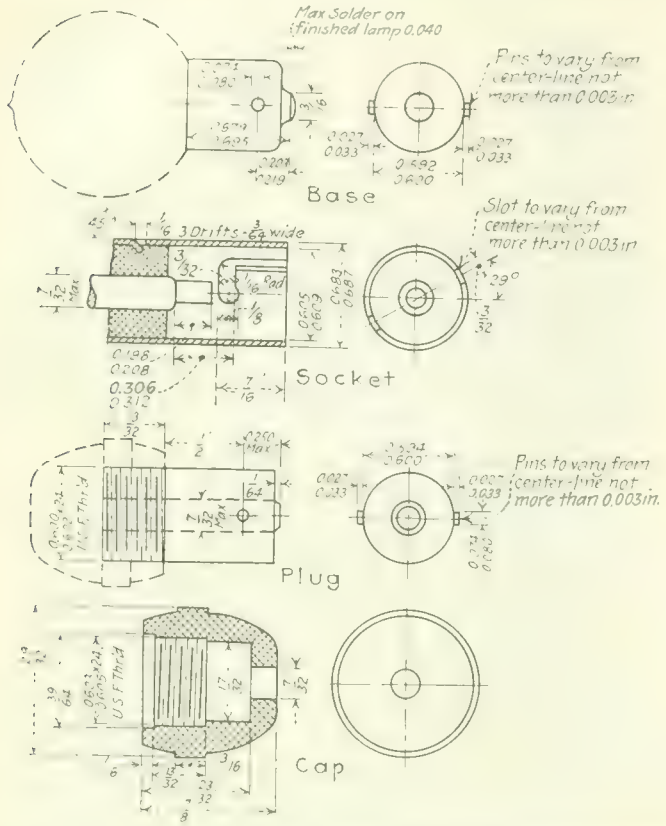

Max Solder on finished lamp 0.040
Pins to vary from center-line not more than 0.003 in.
Base
3 Drifts-3/32 wide
Slot to vary from center-line not more than 0.003 in.
29°
Socket
Pins to vary from center-line not more than 0.003 in.
Plug
Cap

FIG. 39.—ELECTRIC BASE, SOCKET, PLUG AND CAP FOR GROUND RETURN SYSTEM

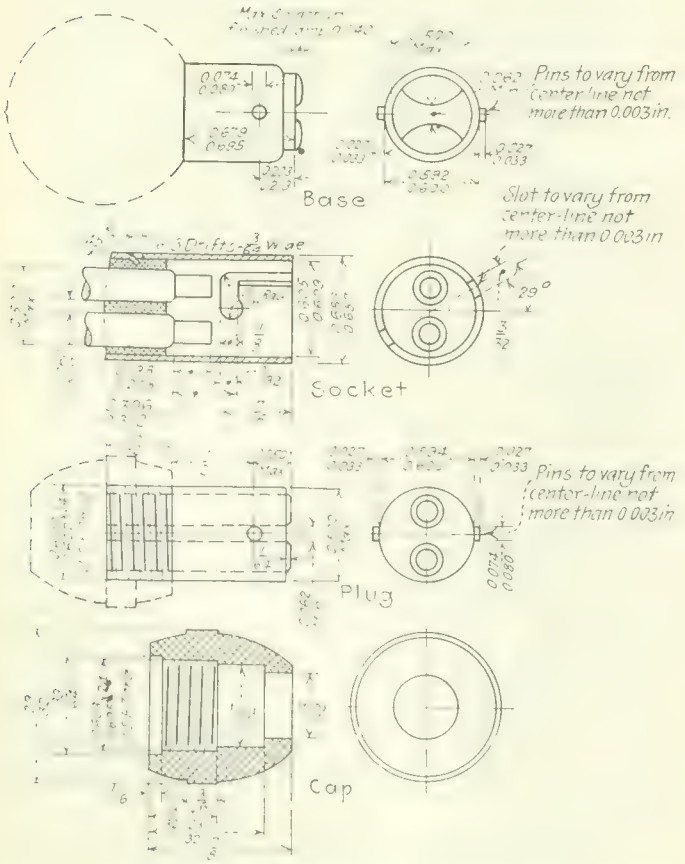

Pins to vary from center-line not more than 0.003 in.
Base
Slot to vary from center-line not more than 0.003 in.
29°
Socket
Pins to vary from center-line not more than 0.003 in.
Plug
Cap

FIG. 40.—ELECTRIC BASE, SOCKET, PLUG AND CAP FOR INSULATED-RETURN SYSTEM

This steel has a limited application in automotive constructions. It has some application in anti-friction bearings and is used extensively for machine-tool parts, being primarily a tool steel.

For all general applications when a normalized and annealed material is to be handled, Heat-Treatment VI is recommended.

When the user forges or hot-presses parts to shape, a special treatment must precede all machining operations.

S.A.E. Steels 9250 *and* 9260

These Notes are not to be considered in any way a part of the standard specifications for S.A.E. Steels. They are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

CHEMICAL COMPOSITION IN PERCENTAGE

Steel	9250	9260
Carbon	0.45-0.55	0.55-0.65
Manganese	0.60-0.90	0.60-0.90
Phosphorus	0.045 max.	0.045 max.
Sulphur	0.045 max.	0.045 max.
Silicon	1.80-2.20	1.80-2.20

These steels have been standardized by usage principally as spring steels. They are also used to some extent for gears with Heat-Treatment VIII. Neither steel is suitable for use without heat-treatment.

As the structure of forgings is less uniform than that of bar stock in most cases, either in the individual piece or between different pieces, normalizing as in Heat-Treatment VIII is recommended as the preliminary treatment for all forgings, but the desired physical properties of bar stock can be obtained generally without normalizing, as in Heat-Treatment VI.

Heat-Treatment 9250-*VI and* 9260-*VI*

1—Heat to 1500 to 1650 deg. fahr.
2—Quench in oil
3—Draw to required hardness or tests

For gears made of this steel, Heat-Treatment VIII is recommended.

Heat-Treatment 9250-*VIII and* 9260-*VIII*

1—Normalize at 1650 to 1750 deg. fahr.
2—Reheat to 1400 to 1450 deg. fahr.
3—Cool slowly
4—Machine
5—Reheat to 1600 to 1650 deg. fahr.
6—Quench
7—Draw to required hardness or tests

LIGHTING DIVISION REPORT

BASES, SOCKETS AND CONNECTORS

(Proposed Revision of S.A.E. Standard)

Th Lighting Division recommends that the following revision of the present S.A.E. Standard for Bases, Sockets and Connectors, page B4, S.A.E. HANDBOOK, covering both the ground-return and insulated-return systems be adopted.

(1) The addition of limits of 0.306 to 0.312 in. for the distance from the end of the plunger sleeve to the top of the locking slot

(2) The elimination of limits of 0 to 1/64 in. for the distance from the top of the plunger when extended to the bottom of the locking slot

(3) The addition of a footnote referring to the locking-pins and slots of the bases, sockets and plugs, to the effect that the variation from the center-line shall not be more than 0.003 in.

This revision is recommended by the Division largely because of the relation between the distance from the top of the plunger when depressed to the top of the locking slot and the maximum distance from the top of the locking pin to the end of the solder of the finished lamp, which might in some cases result in a very tight fit of the lamp base in the socket, if the recommendations specified above were not followed. The present standard revised as proposed is given in Figs. 39 and 40.

Lamp Glasses

(Proposed Revision of S.A.E. Standard)

The Lighting Division recommends that the present S.A.E. Standard for Lamp Glasses, page B6, S.A.E. HANDBOOK, be extended to specify the dimensions of the locking notches in the head-lamp glasses as shown in Fig. 41. These notches are to prevent the glass from turning in the lamp, which is a matter of importance in other than plain lamp-glasses.

The recommendation specifies the use of notches rather than projecting lugs as the latter are likely to be broken off in shipping. Four notches as illustrated are considered advisable as glasses with notches so arranged will fit the greatest number of head-lamps now in use.

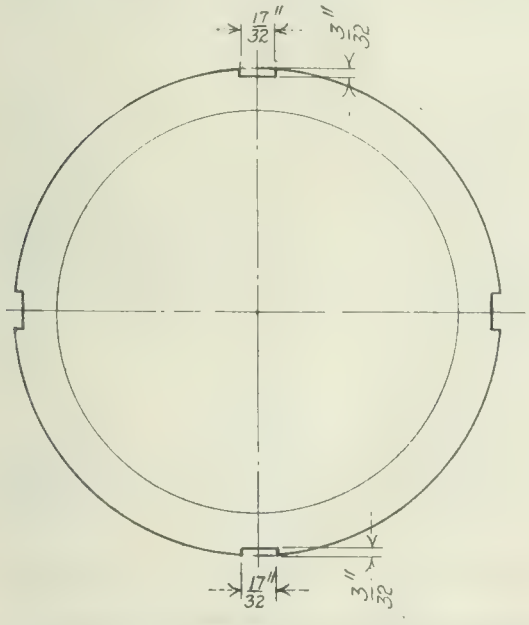
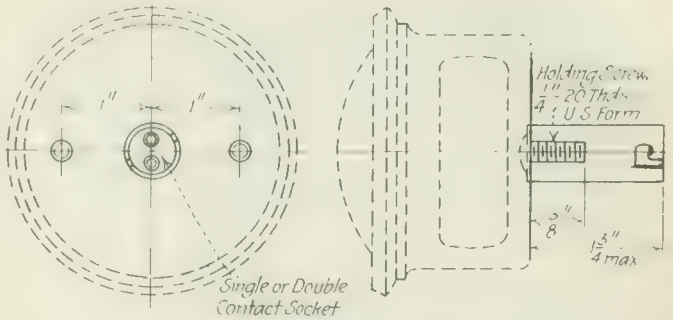


FIG. 41.—PROPOSED ARRANGEMENT OF HEAD-LAMP GLASS RIM TO PREVENT THE GLASS FROM TURNING IN THE RIM

Tail-Lamps

(Proposed S.A.E. Recommended Practice)

The Lighting Division recommends the adoption as S.A.E. Recommended Practice of the tail-lamp mounting-dimensions specified in Fig. 42. The adoption of these dimensions in actual practice will make tail-lamps interchangeable. Lamp dimensions are not specified so as not to limit individuality in design, the important features being the size and location of the mounting studs and the location and maximum projection of the connector. Reduction of the recommendation to practice will eliminate the many different methods of mounting now used and provide for definite clearances and arrangements of electrical connections, thus lessening the cost of manufacturing.



HOLDING SCREWS: Two ¼ in-20 U.S. Form threads ⅝ in long

TAIL-LAMP GLASS DIAMETER: 3 in plus 0, minus 1/32 in.

FIG. 42.—TAIL LAMP OVERALL DIMENSIONS AND MOUNTING SCREWS

NON-FERROUS METALS DIVISION REPORT

Non-Ferrous Metal Specifications

(Proposed Revision of S.A.E. Standard)

At the meeting of the Standards Committee and the Society held last January the Non-Ferrous Metals Division reported a revised and considerably extended list of S.A.E. Non-Ferrous Metal Specifications. As the list is not as complete as desired, the Division has done a large amount of work during the past year with a view to adding to it, as well as revising some of the specifications. The new and revised specifications have been reviewed carefully and wherever possible made to conform with those of the American Society for Testing Materials. The revisions proposed are in accordance with most acceptable current practice and were prepared by Subdivisions representing the respective branches of the non-ferrous metal industries.

SPECIFICATION NO. 1—SOLDER

COMPOSITION IN PERCENTAGE

	Class A	Class B
Tin, minimum	49.50	48.75
Tin, maximum	50.50	49.75
Lead, approximate	50.00	50.00
Antimony, maximum	0.12	0.75
Copper, maximum	0.08	0.15
Zinc and Aluminum	None	None
Other Impurities, maximum	0.10	0.10

General Information The choice of the class and grade of solder for any specified purpose depends on the material in connection with which it is to be used and the method of applying. For galvanized iron and zinc, only Class A should be used. Class A solder should be furnished under this specification unless otherwise specified.

It is recommended that the grade of solder metal be selected that contains the least amount of tin required to give suitable flowing and adhesive qualities for the work in hand.

	Melting Point, deg. cent.	Melting Point, deg. fahr.	Complete Liquation Point, deg. cent.	Complete Liquation Point, deg. fahr.
Class A	181.0	357.8	213.0	415.4
Class B	185.0	365.0	208.0	397.4

SPECIFICATION NO. 2—SOLDER

COMPOSITION IN PERCENTAGE

	Class A	Class B
Tin, minimum	44.50	43.00
Tin, maximum	45.50	44.00
Lead, approximate	55.00	55.00
Antimony, maximum	0.12	1.50
Copper, maximum	0.08	0.15
Zinc and Aluminum	None	None
Other Impurities, maximum	0.10	0.10

General Information The choice of the class and grade of solder for any specified purpose depends on the material in connection with which it is to be used and the method of applying. For galvanized iron and zinc, only Class A should be used. Class A solder should be furnished under this specification unless otherwise specified.

It is recommended that the grade of solder metal be selected that contains the least amount of tin required to give suitable flowing and adhesive qualities for the work in hand.

	Melting Point, deg. cent.	Melting Point, deg. fahr.	Complete Liquation Point, deg. cent.	Complete Liquation Point, deg. fahr.
Class A	181	357.8	225	437.0
Class B	188	370.4	220	428.0

SPECIFICATION NO. 3—SOLDER

COMPOSITION IN PERCENTAGE

	Class A	Class B
Tin, minimum	39.60	37.60
Tin, maximum	40.40	38.40
Lead, approximate	60.00	60.00
Antimony, maximum	0.12	2.00
Copper, maximum	0.08	0.15
Zinc and Aluminum	None	None
Other Impurities, maximum	0.10	0.10

General Information The choice of the class and grade of solder for any specified purpose depends on the material in connection with which it is to be used and the method of applying. For galvanized iron and zinc, only Class A should be used. Class A solder should be furnished under this specification unless otherwise specified.

It is recommended that the grade of solder metal be selected that contains the least amount of tin required to give suitable flowing and adhesive qualities for the work in hand.

	Melting Point, deg. cent.	Melting Point, deg. fahr.	Complete Liquation Point, deg. cent.	Complete Liquation Point, deg. fahr.
Class A	181	357.8	237	458.6
Class B	188	370.4	228	442.4

SPECIFICATION NO. 4—SOLDER

COMPOSITION IN PERCENTAGE

	Class A	Class B
Tin, minimum	24.50	22.50
Tin, maximum	25.50	23.50
Lead, approximate	75.00	75.00
Antimony, maximum	0.12	2.00
Copper, maximum	0.08	0.15
Zinc and Aluminum	None	None
Other Impurities, maximum	0.10	0.10

General Information This solder is recommended for use on work that is to be coated with enamel and then baked as it will withstand higher baking temperatures than solders containing larger amounts of tin.

The choice of the class and grade of solder for any specified purpose depends on the material in connection with which it is to be used and the method of applying. For galvanized iron and zinc, only Class A should be used. Class A solder should be furnished under this specification unless otherwise specified.

It is recommended that the grade of solder metal be selected that contains the least amount of tin required to give suitable flowing and adhesive qualities for the work in hand.

	Melting Point, deg. cent.	Melting Point, deg. fahr.	Complete Liquation Point, deg. cent.	Complete Liquation Point, deg. fahr.
Class A	181	357.8	268	514.5
Class B	188	370.4	258	496.5

SPECIFICATION NO. 14—BABBITT

COMPOSITION IN PERCENTAGE

Tin, minimum	9.25
Tin, maximum	10.75
Antimony, minimum	14.00
Antimony, maximum	16.00
Lead, minimum	74.00
Lead, maximum	76.00
Copper, maximum	0.50
Iron	None
Arsenic, maximum	0.20
Zinc	None
Aluminum	None

General Information This is a cheap babbitt and serves successfully where the bearings are large and the service light. It should not be used as a substitute for a babbitt with a high tin-content. It is also suitable for die-castings.

SPECIFICATION NO. 43—MANGANESE BRONZE

COMPOSITION IN PERCENTAGE

Copper, minimum	53.00
Copper, maximum	62.00
Zinc, minimum	38.00
Zinc, maximum	47.00
Lead, maximum	0.15

This metal may be hardened by the addition of small amounts of tin, iron, manganese, aluminum, or a combination of these metals. Good sand castings made of this alloy should give the following minima in physical characteristics.

Tensile-Strength, lb. per sq. in.	60,000
Yield-Point, lb. per sq. in.	30,000
Elongation in 2 In. or Proportionate Gage-Length, per cent	15

For the purpose of inspection, the most importance should be placed on the following minima in physical requirements on a special chill cast ½-in. test-bar. This test-bar shall be cut from one corner, near the bottom of the test ingot, cast in a properly tapered iron mold, approximately 3 in. deep by 2¾ in. wide by 12 in. long.

Tensile-Strength, lb. per sq. in.	70,000
Elongation in 2 In., per cent	20

General Information This alloy is intended for use in castings where strength and toughness are required. It is equivalent to the copper-zinc alloys commercially known as cast manganese bronze or its equivalents, such as cast tobin bronze and cast naval bronze.

SPECIFICATION NO. 44—CAST BRASS TO BE BRAZED

COMPOSITION IN PERCENTAGE

Copper, minimum	83.00
Copper, maximum	86.00
Zinc, minimum	14.00
Zinc, maximum	17.00
Lead, maximum	0.50
Iron, maximum	0.15

General Information This brass starts to melt at approximately 1830 deg. fahr. and is entirely melted at approximately 1870 deg. fahr. As a brazing material on this brass to be brazed either Silver Solder or a brazing brass melting at a temperature lower than the brass to be brazed should be used.

SPECIFICATION NO. 45—BRAZING SOLDER

COMPOSITION IN PERCENTAGE

Copper, minimum	48.00
Copper, maximum	52.00
Lead, maximum	0.50
Iron, maximum	0.10
Zinc	Remainder

General Information This solder starts to melt at approximately 1560 deg. fahr. and is entirely melted at approximately 1600 deg. fahr. It may be used by melting it in a crucible under a flux of borax, with or without the addition of boric acid, and dipping the material to be brazed in the melted brazing solder; or this brazing solder, in a powdered form, may be mixed with the flux applied to the material to be brazed, and melted either in a furnace or by the use of a brazing torch.

SPECIFICATION NO. 70—COMMERCIAL BRASS SHEET

COMPOSITION IN PERCENTAGE

Copper, minimum	64.50
Copper, maximum	67.50
Lead, maximum	0.30
Iron, maximum	0.05
Other Impurities, maximum	0.10
Zinc	Remainder

MECHANICAL REQUIREMENTS

Temper and Anneal.—The temper of the sheet brass shall be designated as follows:

	Reduction, B. & S. Gage Nos.
Quarter Hard	1
Half Hard	2
Hard	4
Extra Hard	6
Spring	8

The annealed sheet shall be designated as Light Anneal, Drawing Anneal or Soft Drawing Anneal.

The average Brinell hardness of 10 samples of sheet 0.080 in. or over in thickness shall be within the following limits:

Quarter Hard	75 to 95
Half Hard	95 to 115
Hard	130 to 150
Extra Hard	150 to 170
Spring	160 to 180
Light Anneal	65 to 75
Drawing Anneal	55 to 65
Soft Drawing Anneal	47 to 55

The average of tension tests of two samples of sheet thinner than 0.080 in. shall conform to the following minimum requirements:

Temper	Tensile-Strength, lb., per sq. in.	Elongation in 2 In., per cent.
Quarter Hard	45,000	27.5
Half Hard	52,500	15.0
Hard	67,500	5.0
Extra Hard	80,000	2.0
Spring	87,500	1.0
Light Anneal	45,000	32.0
Drawing Anneal	42,000	38.0
Soft Drawing Anneal	40,000	42.0

In very thin strips, on account of the difficulties in testing, the elongation may be considerably less than the figures given.

PERMISSIBLE VARIATIONS IN THICKNESS, IN.

Thickness, B. & S. Gage No.		Thickness, in.		Width, in.			
From	To	From	To	Up to 5, Inclusive	Over 5, to 8, Inclusive	Over 8, to 11, Inclusive	Over 11, to 14, Inclusive
0000	0	0.4600	0.3248	±0.0044	±0.0048	±0.0051	±0.0055
Below 0	4	0.3248	0.2043	±0.0039	±0.0043	±0.0046	±0.0050
4	8	0.2043	0.1284	±0.0034	±0.0038	±0.0041	±0.0045
8	14	0.1284	0.0640	±0.0029	±0.0033	±0.0036	±0.0040
14	18	0.0640	0.0403	±0.0025	±0.0029	±0.0033	±0.0037
18	24	0.0403	0.0201	±0.0020	±0.0024	±0.0028	±0.0032
24	28	0.0201	0.0126	±0.0016	±0.0020	±0.0024	±0.0028
28	32	0.0126	0.0079	±0.0013	±0.0017	±0.0020	±0.0024
32	35	0.0079	0.0056	±0.0010	±0.0014	±0.0017	±0.0022
35	38 Incl.	0.0056	0.0039	±0.0008	±0.0012	±0.0015	±0.0019

These should be considered as general specifications. Since high brass is used for many purposes where the requirements of the operations used are too particular to be specified by any of the ordinary physical tests, it is frequently advisable to submit samples or drawings to the manufacturer and secure an adjustment of anneal or temper to suit the actual operations to which the material is to be submitted.

SPECIFICATION NO. 71—COPPER SHEET

COMPOSITION IN PERCENTAGE

Copper, minimum	99.50

MECHANICAL REQUIREMENTS

TENSILE-STRENGTH AND ELONGATION, SOFT COPPER

Thickness, in.	Tensile-Strength, maximum, lb. per sq. in.	Elongation in 2 In., minimum, per cent
0.005 to 0.031	37,000	20.0
0.032 to 0.375	36,000	25.0

TENSILE-STRENGTH AND ELONGATION, HARD COPPER

Thickness, in.	Tensile-Strength, minimum, lb. per sq. in.	Elongation in 2 In., minimum, per cent
Less than .072	As hard as possible to stand bending cold through an angle of 180 deg. flat back without fracture on the outside of the bent portion.	
0.072 to 0.375	40,000	8.0
over 0.375	35,000	15.0

PERMISSIBLE VARIATIONS IN THICKNESS, IN.

Thickness, B. & S. Gage No.		Thickness, in.		Width, in.			
From	To	From	To	Up to 5, Inclusive	Over 5, to 8, Inclusive	Over 8, to 11, Inclusive	Over 11, to 14, Inclusive
0000	0	0.4600	0.3248	±0.0044	±0.0048	±0.0051	±0.0055
Below 0	4	0.3248	0.2043	±0.0039	±0.0043	±0.0046	±0.0050
4	8	0.2043	0.1284	±0.0034	±0.0038	±0.0041	±0.0045
8	14	0.1284	0.0640	±0.0029	±0.0033	±0.0036	±0.0040
14	18	0.0640	0.0403	±0.0025	±0.0029	±0.0033	±0.0037
18	24	0.0403	0.0201	±0.0020	±0.0024	±0.0028	±0.0032
24	28	0.0201	0.0126	±0.0016	±0.0020	±0.0024	±0.0028
28	32	0.0126	0.0079	±0.0013	±0.0017	±0.0020	±0.0024
32	35	0.0079	0.0056	±0.0010	±0.0014	±0.0017	±0.0022
35	38 Incl.	0.0056	0.0039	±0.0008	±0.0012	±0.0015	±0.0019

SPECIFICATION NO. 73—NAVAL BRASS (TOBIN BRONZE) ROD

COMPOSITION IN PERCENTAGE

Copper, minimum	59.00
Copper, maximum	62.00
Tin, minimum	0.50
Tin, maximum	1.50
Iron, maximum	0.10
Lead, maximum	0.30
Other Impurities, maximum	0.10
Zinc	Remainder

MECHANICAL REQUIREMENTS

TENSILE-TEST DATA

Diameter or Thickness, in.		Minimum Tensile -Strength, lb. per sq. in.	Minimum Yield -Point, lb. per sq. in.	Minimum Elongation in 2 In., per cent.
Over	To and Including			
0	1	62,000	31,000	25.0
1	2½	60,000	30,000	30.0
2½	3½	56,000	25,000	35.0
3½		54,000	22,000	40.0

Strain Test A full-size test-specimen must stand immersion for 15 min. without cracking in an aqueous

solution containing 100 grams of mercurous nitrate and 13 cc. of nitric acid of specific gravity 1.42 per liter.

Bend Test The rods shall stand cold-bending without fracture through an angle of 120 deg. around a pin, the radius of which is equal to the diameter or thickness of the rod or bar.

Dimensions and Tolerances The diameter of round sections shall not vary from that specified by more than the tolerances specified in the following table:

Diameter, in.		Tolerances, in.
Over	To and Including	
0	$\frac{1}{2}$	±0.0015
$\frac{1}{2}$	1	±0.0020
1	$2\frac{1}{2}$	±0.0025
$2\frac{1}{2}$		±0.0030

In case of other than round sections the distance between parallel faces shall be permitted to vary, in their respective sizes, double the amount of the above tolerances.

General Information This material is intended for use wherever brass rod that is stronger, tougher, and less corrodible than commercial brass rod is required.

SPECIFICATION NO. 76—NAVAL BRASS (TOBIN BRONZE) TUBING

COMPOSITION IN PERCENTAGE

Copper, minimum	59.00
Copper, maximum	62.00
Tin, minimum	0.50
Tin, maximum	1.50
Iron, maximum	0.10
Lead, maximum	0.30
Other Impurities, maximum	0.10
Zinc	Remainder

MECHANICAL REQUIREMENTS

TENSILE-TEST DATA

Thickness of Wall, in.		Minimum Tensile -Strength, lb. per sq. in.	Minimum Yield -Point, lb. per sq. in.	Minimum Elongation in 2 In., per cent
Over	To and Including			
0	$\frac{1}{8}$	60,000	24,000	28
$\frac{1}{8}$	$\frac{1}{4}$	55,000	22,000	32
$\frac{1}{4}$		50,000	20,000	35

DIMENSIONAL TOLERANCES

Outside Diameter, in.		Tolerances,[12] in.	Wall Thickness, in.		Tolerances,[13] in.
Over	To		Over	To	
$\frac{1}{2}$	$\frac{3}{4}$	±0.0025	$\frac{1}{64}$	$\frac{1}{32}$	±0.0020
$\frac{3}{4}$	1	±0.0030	$\frac{1}{32}$	$\frac{1}{16}$	±0.0030
1	$1\frac{1}{4}$	±0.0035	$\frac{1}{16}$	$\frac{1}{8}$	±0.0050
$1\frac{1}{4}$	$1\frac{1}{2}$	±0.0040	$\frac{1}{8}$	$\frac{1}{4}$	±0.0080
$1\frac{1}{2}$	$1\frac{3}{4}$	±0.0045	$\frac{1}{4}$	$\frac{5}{16}$	±0.0125
$1\frac{3}{4}$	2	±0.0050	$\frac{5}{16}$	$\frac{3}{8}$	±0.0150
2		±0.0025 xDiam.			

[12] Either inside or outside diameter.

[13] No combination of variations on the same tube shall make the thickness of the wall vary from the nominal by more than these amounts.

Expanding Test A pin having a taper of 1 to 8 shall be driven into one end of a tube until the diameter is increased 15 per cent. The tube shall withstand this test without showing cracks, splits or other defects.

Appearance These tubes shall be clean, smooth and free from injurious defects, both inside and outside.

Special Limits On all stock where the above commercial variations are not permissible, the limits shall be specified in the order.

SPECIFICATION NO. 80—BRASS SPRING WIRE

COMPOSITION IN PERCENTAGE

	Grade A	Grade B
Copper, minimum	70.00	64.00
Copper, maximum	74.00	68.00
Lead, maximum	0.10	0.10
Iron, maximum	0.06	0.07
Zinc	Remainder	Remainder

Physical Properties This wire shall have a tensile-strength of at least 100,000 lb. per sq. in., but should be capable of being bent through an angle of 180 deg. around a wire of the same diameter without breaking.

Appearance The wire shall be uniform in quality and temper, cylindrical in shape and smooth and free from injurious defects.

Grade A is for use where the requirements are especially severe. Grade B is for use under ordinary conditions, and will be furnished unless otherwise specified.

Dimensional Tolerances.—The wire shall not vary from the specified diameter by more than plus or minus 1 per cent for sizes larger than 0.050 in.

From 0.050 to 0.025 in. the variation in size shall not be more than plus or minus 0.0005 in.

For sizes smaller than 0.025 in. the variation shall not be more than plus or minus 0.00025 in.

SPECIFICATION NO. 81—PHOSPHOR BRONZE SPRING WIRE

COMPOSITION IN PERCENTAGE

Tin, minimum	4.00
Tin, maximum	6.00
Phosphorus, minimum	0.03
Phosphorus, maximum	0.40
Zinc, maximum	0.20
Iron, maximum	0.10
Lead, maximum	0.10
Copper	Remainder

MECHANICAL REQUIREMENTS

Wire Diameter, in.	Minimum Tensile-Strength lb. per sq. in.
Up to and including 0.0625	130,000
Above 0.0625 to and including 0.1250	120,000
Above 0.1250 to and including 0.2500	110,000
Above 0.2500 to and including 0.3750	100,000

Bend Test The wire shall be capable of being bent through an angle of 180 deg. flat back on itself without fracture on the outside of the bent portion.

Appearance The wire shall be uniform in quality and temper, cylindrical in shape and smooth and free from injurious defects.

Dimensional Tolerances The wire shall not vary from the specified diameter by more than plus or minus 1 per cent for sizes larger than 0.050 in.

From 0.050 to 0.025 in. the variation in size shall not be more than plus or minus 0.0005 in.

For sizes smaller than 0.025 in. the variation shall not be more than plus or minus 0.00025 in.

SPECIFICATION NO. 88—BRASS FORGING ROD

MECHANICAL REQUIREMENTS

Flattening Test Specimens cut from rods or bars and having a length equal to the diameter of the specimen, shall stand flattening in a axial direction while hot,

until reduced to 20 per cent of their original length, without cracking.

COMPOSITION IN PERCENTAGE

Copper, minimum	58.50
Copper, maximum	61.50
Lead, minimum	1.50
Lead, maximum	2.50
Iron, maximum	0.15
Materials other than Copper, Lead and Zinc, maximum	0.35
Zinc	Remainder

When the sample is taken from several bars or rods, for analysis, it should meet this specification. If only one rod or bar is sampled, the following composition in percentage will be acceptable.

Copper	57.9 to 62.1
Lead	1.2 to 3.0

Dimensions and Tolerances The diameter of the round sections shall not vary from that specified by more than the tolerances specified in the following table:

Diameter, in.		Tolerances, in.
Over	To and Including	
0	½	±0.005
½	1	±0.008
1	2½	±0.010
2½		±0.015

General Information These specifications cover brass rods of any specified cross-section capable of being readily forged while hot and easily machined.

The rods may be manufactured either by hot-rolling or extrusion, and may be finished by cold-drawing if necessary to meet the requirements for size.

PARTS AND FITTINGS DIVISION REPORT

Rod-Ends

(Proposed Revision of S.A.E. Standard)

Definite diameters of the pin-boss on the adjustable and plain yoke-ends have never been incorporated in the S.A.E. Standard for Rod-Ends, page C8, S.A.E. Handbook. As doubt has arisen at times as to what these diameters should be, the Parts and Fittings Division has communicated with the forging and automobile manufacturers to check present practice and to obtain approval of the additions and revisions of the existing standard recommended. It is believed that the recommendations will be entirely acceptable to all the manufacturers and it is therefore recommended that the following be incorporated in the present S.A.E. Standard

(1) Specify dimension *K* as the diameter of the pin-bosses on the drawings for the adjustable and plain yoke-rod-ends, the same as now specified for the pin-boss of the eye-rod-end

(2) Change dimension *K* in the table for the ⅞-in. size from 1-13/16 to 1-11/16 in.

Taper Fitting for Plain or Slotted Nuts

(Proposed Extension of S.A.E. Standard)

The Parts and Fittings Division recommends that the present S.A.E. Standard for Taper Fittings with Plain or Slotted Nuts, page C14, S.A.E. Handbook, be revised by the addition of a footnote reading

> The center-line of the cotter-pin hole shall be 90 deg. from the position of the keyway as shown on the drawing.

The Division makes this recommendation to establish definitely the location of the cotter-pin hole with respect to the position of the keyway in taper fittings, inasmuch as the hole is sometimes specified in line with the keyway and sometimes at 90 deg. to it. Adoption of the proposed revision will unify practice.

Water-Pipe Flanges

(Proposed S.A.E. Recommended Practice)

The Parts and Fittings Division recommends for adoption as S.A.E. Recommended Practice the water-pipe flange dimensions specified in Table 13.

This recommendation will supersede the present S.A.E. Recommended Practice specifying that the standard two and four-bolt types of carbureter flange, page A8, S.A.E. Handbook, shall be used for motorboat water-pipe flanges. The type of flange now recommended by the Division is considered satisfactory for general automotive practice, and has been approved by the members of the Motorboat Division.

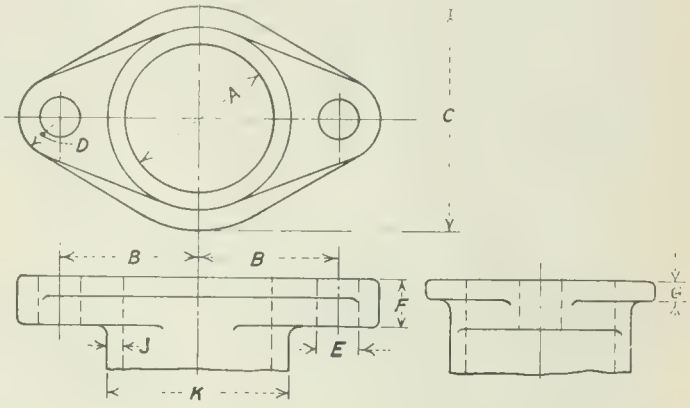


Fig. 41—Water-Pipe Flanges

TABLE 13—PROPOSED DIMENSIONS OF WATER-PIPE FLANGES

Nominal Flange Size, in.	1 3/16	1 7/16	1 11/16	1 15/16	2 3/16
Outside Diameter (*K*), in.	1 1/2	1 3/4	2	2 1/4	2 1/2
Inside Diameter (A), in.	1 3/16	1 7/16	1 11/16	1 15/16	2 3/16
B	1 3/16	1 11/32	1 15/32	1 21/32	1 25/32
C	1 7/8	2 3/16	2 1/2	2 13/16	3 1/8
D	11/32	13/32	13/32	15/32	15/32
E	11/32	13/32	13/32	15/32	15/32
F	13/32	15/32	15/32	9/16	9/16
G	7/32	1/4	1/4	9/32	9/32
Length,[14] in.	1 1/4	1 1/4	1 1/4	1 1/4	1 1/2
J	5/32	5/32	5/32	5/32	5/32
Capscrews	5/16-18	3/8-16	3/8-16	7/16-14	7/16-14

[14] Length of fitting for lap of hose.

The present S.A.E. Standard for Radiators specifies that the water inlet and outlet flanges shall be the same as the S.A.E. Standard two-bolt carbureter flanges. It also specifies that such fittings shall be cast separate from the radiator tank to avoid the danger of being broken off during transportation and because in many instances the automobile manufacturers purchase these fittings from other sources than the radiator manufacturers.

The proposed outside diameters and the lengths of the fittings for the lap of hose are in accord with the S.A.E. Standard for Rubber Hose Clamps and Fittings, page C51, S.A.E. Handbook.

Lock-Washers

(Proposed Revision of S.A.E. Standard)

The former Miscellaneous Division, now incorporated in the Parts and Fittings Division, considered a revision of the present S.A.E. Standard for Lock-Washers, page C5, S.A.E. Handbook, which was adopted in 1911. Developments in the automotive industry since 1911 have brought about more accurate screw-thread practice and the general use of softer metals which require lighter lock-washers. Reconsideration of the present standard was initiated by the Motorcycle Division which requested the Parts and Fittings Division to formulate a series of extra-light lock-washers for use in the motorcycle industry.

E. W. Hart, who is Chairman of the Standardization Committee of the Association of Lock Washer Manufacturers, was appointed a Subdivision to make a special study of this subject.

He submitted a tentative report which was published on page 119 of the August issue of The Journal with a request for criticisms. As a result of comments received the Subdivision report was approved with minor changes by the Division as given in Table 15 and is recommended for adoption as S.A.E. Standard. The recommendation is intended for application to all types of automotive apparatus.

PASSENGER-CAR BODY DIVISION REPORT

Passenger-Car Door Handles

(Proposed S.A.E. Recommended Practice)

At the March 1921 meeting of the Passenger-Car Body Division it was suggested that the cross-section of the square shaft of door-handles should be standardized so as to permit interchangeability of handles and locks. A Subdivision was appointed and submitted a preliminary report that was referred to passenger car and body engineers for comment. As a result of the Subdivision's report and the comments received, the Division recommends for adoption as S.A.E. Recommended Practice the door-handle squares illustrated in Figs. 42 and 43.

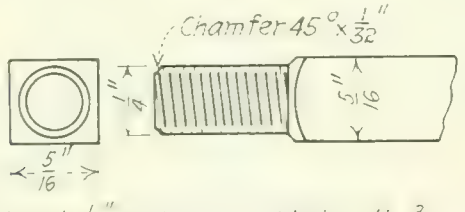


Fig. 42—Internally-Threaded Type of Door Handle Squares

The Division is of the opinion that the construction recommended is more suitable for a standard as compared with countersunk internally threaded squares because it can be more readily fitted to come flush with the door-handles when assembling. The externally threaded type is included in the recommendation, however, for those who prefer this type of construction.

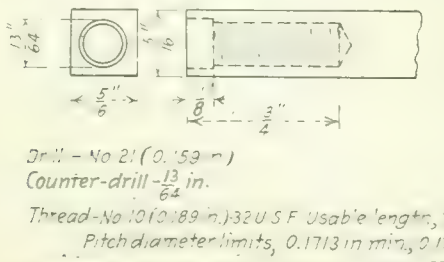

13/64"
5/16"
5/16"
5/8"
3/4"
Drill - No 21 (0.159 in.)
Counter-drill - 13/64 in.
Thread - No 10 (0.189 in.) - 32 U.S.F. Usable length, 5/8 in.
Pitch diameter limits, 0.1713 in min., 0.1718 in max.

Fig. 43—Internally-Threaded Type of Door Handle Squares

Some criticisms of the Subdivision's report indicated that the recommended tolerances of plus or minus 0.001 in. are too small, but it was the opinion of the Division that these tolerances should be specified, particularly as several large consumers of key-stock specify them.

Passenger-Car Doors

(Proposed S.A.E. Recommended Practice)

The Passenger-Car Body Division recommends that the door-fit clearances given in Table 14 be adopted as S.A.E. Recommended Practice. The nominal door-fit clearances recommended were submitted to passenger-car engineers for comment and met with general approval. It was suggested by several, however, that tolerances should be specified and the recommendation of the Division as submitted has therefore been extended to cover tolerances which are in accord with good body practice.

The Division also recommends that door-flange widths shall be 5/16 in. on the hinge-pillar side and ½ in. minimum on the lock-pillar side and on the bottom. The door-fit tolerances specified do not apply to flush-type doors.

TABLE 14—PROPOSED DOOR-FIT CLEARANCES

Location	Clearance, in.
Hinge Side	1/8, ± 1/32
Lock Side	3/16, + 1/16, — 0
Bottom	1/4, + 1/16, — 0
Top	1/8, ± 1/32
Jamb	3/16, + 1/16, — 0
Bead	3/32, + 1/32, — 0

These clearances are for all types of body, and are measured from wood-to-wood or metal-to-metal before painting.

Door-flange widths shall be 5/16 in. on the hinge-pillar side and ½ in. minimum on the lock-pillar side and on the bottom.

Rubber Bushings

(Proposed S.A.E. Recommended Practice)

The Passenger-Car Body Division recommends the adoption of the following proposal as S.A.E. Recommended Practice because grommets or bushings for electric wiring or conduit when inserted in plain holes punched in sheet metal are quickly cut by the sharp edges and it is a relatively simple and effective process to form a neck to the hole when punching.

Where holes are punched in sheet metal for carrying grommets or bushings, particularly when these are made of rubber, it is recommended that the holes be necked.

Wiring for Beads

(Proposed S.A.E. Recommended Practice)

The Passenger-Car Body Division recommends the adoption of the following proposal for S.A.E. Recommended Practice to simplify the manufacture of parts in which a beaded construction is used such as fenders and splash guards, and to economize in the number of sizes of wire used. The proposal was prepared by a Subdivision and is founded on data indicating the current general practice.

For engine hoods up to and including 36 in. long, top hinge-rods shall be 5/16-in. diameter, and side hinge-rods shall be ¼-in. diameter

For fenders, aprons and splash-guards the wire used for beading shall be No. 11 B.w.g. bright basic steel wire.

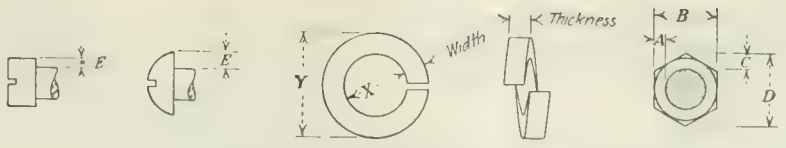


TABLE 15.—PROPOSED DIMENSIONS OF LOCK WASHERS.

Fillister Head Machine Screws

Screw Number	Diameter		Clearance[15]	E	X	Standard		Special Light		Special Heavy	
	Screw	Head				Section[16]	Y	Section[16]	Y	Section[16]	Y
2	0.086	0.132	0.003	0.023	0.089	1/32×0.022	0.1515	0.022×0.022	0.1330	1/32×1/32	0.1515
4	0.112	0.175	0.003	0.031	0.115	1/32×1/32	0.1775	1/32×0.022	0.1775	3/64×1/32	0.2087
6	0.138	0.217	0.005	0.040	0.143	3/64×1/32	0.2367	1/32×1/32	0.2055	3/64×3/64	0.2367
8	0.164	0.260	0.005	0.048	0.169	3/64×3/64	0.2627	3/64×1/32	0.2627	1/16×3/64	0.2940
10	0.190	0.303	0.010	0.056	0.200	1/16×3/64	0.3250	3/64×3/64	0.2937	1/16×1/16	0.3250
12	0.216	0.345	0.010	0.065	0.226	1/16×1/16	0.3510	1/16×3/64	0.3510	5/64×1/16	0.3822

Round Head Machine Screws

2	0.086	0.154	0.003	0.034	0.089	1/32×1/32	0.1515	1/32×0.022	0.1515	3/64×1/32	0.1827
4	0.112	0.202	0.003	0.045	0.115	1/16×1/32	0.2400	3/64×1/32	0.2087	5/64×1/32	0.2712
6	0.138	0.250	0.005	0.056	0.143	5/64×1/32	0.2992	1/16×1/32	0.2680	5/64×3/64	0.2992
8	0.164	0.298	0.005	0.067	0.169	5/64×3/64	0.3252	5/64×1/32	0.3252	3/32×3/64	0.3565
10	0.190	0.346	0.010	0.078	0.200	3/32×3/64	0.3875	5/64×3/64	0.3562	3/32×1/16	0.3875
12	0.216	0.394	0.010	0.089	0.226	3/32×1/16	0.4135	3/32×3/64	0.4135	1/8×3/64	0.4760

S. A. E. Standard Bolts

Bolt Diameter	Clearance[15]	A	B	C	D	X	Standard		Special Light		Special Heavy	
							Section[16]	Y	Section[16]	Y	Section[16]	Y
1/4	1/32	3/32	3/8	0.128	0.505	9/32	3/32×1/16	15/32	3/32×3/64	15/32	3/32×5/64	15/32
5/16	1/32	3/32	1/2	0.133	0.578	11/32	1/8×1/16	19/32	1/8×3/64	19/32	1/8×3/32	19/32
3/8	1/32	3/32	9/16	0.137	0.650	13/32	1/8×3/32	21/32	1/8×1/16	21/32	1/8×1/8	21/32
7/16	1/32	3/32	5/8	0.173	0.722	15/32	5/32×1/8	25/32	5/32×1/16	25/32	5/32×5/32	25/32
1/2	1/32	1/8	3/4	0.183	0.866	17/32	11/64×1/8	7/8	11/64×1/16	7/8	11/64×11/64	7/8
9/16	1/32	5/32	7/8	0.224	1.011	19/32	3/16×1/8	31/32	3/16×3/32	31/32	3/16×3/16	31/32
5/8	1/32	5/32	15/16	0.229	1.083	21/32	13/64×5/32	1 1/16	13/64×3/32	1 1/16	13/64×13/64	1 1/16
11/16	1/32	5/32	1	0.234	1.156	23/32	7/32×3/16	1 5/32	7/32×1/8	1 5/32	7/32×7/32	1 5/32
3/4	1/16	5/32	1 1/16	0.239	1.228	13/16	1/4×3/16	1 5/16	1/4×1/8	1 5/16	1/4×1/4	1 5/16
7/8	1/16	3/16	1 1/4	0.284	1.444	15/16	17/64×3/16	1 15/32	17/64×5/32	1 15/32	17/64×17/64	1 15/32
1	1/16	7/32	1 7/16	0.330	1.660	1 1/16	5/16×1/4	1 11/16	5/16×3/16	1 11/16	5/16×5/16	1 11/16
1 1/8	1/16	1/4	1 5/8	0.376	1.877	1 3/16	3/8×1/4	1 15/16	3/8×3/16	1 15/16	3/8×3/8	1 15/16
1 1/4	1/16	9/32	1 13/16	0.422	2.093	1 5/16	7/16×1/4	2 3/16	7/16×3/16	2 3/16	7/16×5/16	2 3/16
1 3/8	1/16	5/16	2	0.468	2.310	1 7/16	7/16×5/16	2 5/16	7/16×1/4	2 5/16	7/16×3/8	2 5/16
1 1/2	1/16	11/32	2 3/16	0.513	2.527	1 9/16	1/2×5/16	2 9/16	1/2×1/4	2 9/16	1/2×3/8	2 9/16

All dimensions in inches.

[15] Inside diameter of washer less diameter of bolt or screw.

[16] Lock-washer sizes should be designated by giving the bolt diameter, the lock-washer width and the thickness in the order given; as 1/2 × 11/64 × 1/8.

Investigation of this whole subject indicated that there is a tendency to make fenders without beads, but the Division does not consider such practice desirable as it leaves the fender edges sharp.

Body Nomenclature

(Proposed Revision of S.A.E. Standard)

One of the important subjects considered by the Passenger-Car Body Division is the selection of appropriate names for the several types of passenger-car bodies. The present variety of names applied to given types of body tends toward confusion in the minds of passenger-car purchasers and creates difficulties for the sales and service departments of the automobile manufacturers. A Subdivision drafted a series of suggested names for bodies which was circularized to secure suggestions. The comments submitted formed the basis for further consideration of the subject and indicated to the Division the necessity for standardization of body nomenclature, although, no matter what nomenclature is eventually adopted, various terms will probably continue to be used. The members of the Division, in reaching their conclusions, have borne in mind the derivations of the several terms, their application to their now more or less obsolete horse-drawn prototypes and the accepted European or international usage.

The use of the illustrations with the descriptions of the various types of body is recommended as the best method of indicating clearly what each type represents. The Division also recommends that other national organizations such as the National Automobile Chamber of Commerce, the American Automobile Association, the Automobile Body Builders Association, the Carriage Builders National Association, and the Vehicle Manufacturers Association, as well as the automotive press, give the recommendation their support by urging upon all manufacturers and distributors of automobiles the desirability of adhering to the standard nomenclature. This report is intended to supersede the present standard body-nomenclature printed on pages K20 and K21 of the S.A.E. Handbook.

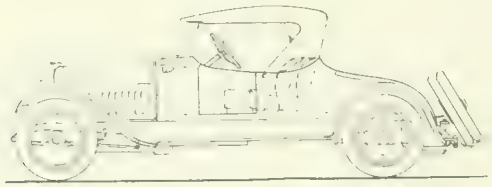


Fig. 44—Roadster

Roadster (Fig. 44)—A small open-type body, having one fixed cross-seat for two passengers and a space or compartment at the rear for carrying luggage. Folding seats fitting into the luggage compartment are sometimes used. The conventional type has two doors and a folding roadster top with emergency side-curtains that are removable.

Coupe (Fig. 45) — An enclosed single-compartment body, with one fixed cross-seat. This seat may be straight and accommodate two persons or be staggered and accommodate three persons. With the latter arrangement, a folding seat may be placed beside the driver's seat, thus making it a four-passenger body. The conventional body has two doors and two movable

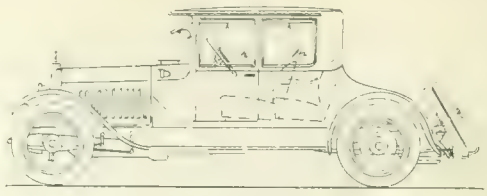


Fig. 45—Coupe

glass windows on each side, the roof is permanent, and there is a luggage compartment at the rear.

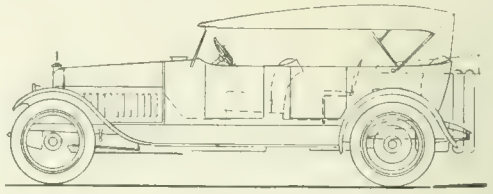


Fig. 46—Phaeton

Phaeton[17] (Fig. 46) — An open-type body, with two fixed cross-seats for four or five passengers. Folding seats in the tonneau for two additional passengers are sometimes used. The conventional body has four doors and a folding phaeton-top with emergency side-curtains that are removable.

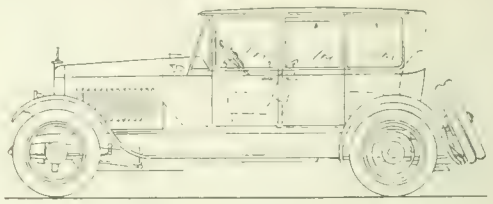


Fig. 47—Sedan

Sedan (Fig. 47) — An enclosed single-compartment body, with two fixed cross-seats for four or five passengers. Sometimes the front seat is divided by an aisle. Folding seats in the tonneau for two additional passengers are sometimes used. The conventional body has four doors, but some models have only two. There are three movable glass windows on each side and the roof is non-collapsible.

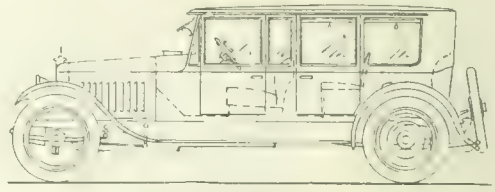


Fig. 48—Berline

Berline (Fig. 48) — A body of the same general description as the sedan, except that there is a partition at the rear of the driver's seat that makes it an enclosed two-compartment body. Generally one glass window in the partition is made so that it can be moved horizontally or vertically.

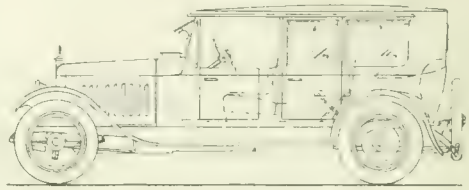


Fig. 49—Limousine

Limousine (Fig. 49)—A partially enclosed body, with a non-collapsible roof that extends the full length of the body and is attached at the front to the windshield standards. Only the rear portion of the body up to the partition at the rear of the driving seat is fully enclosed. Forward of this partition, the sides are en-

[17] The principal reason for recommending the use of the term "phaeton" instead of the term "touring" is that the latter has lost its significance as applying to any particular type of body, as all types are used for touring. The term "phaeton" is used extensively in Europe and to a considerable extent in America in connection with passenger-cars; it is the name of a horse-drawn prototype; it is inelegant and in a technical sense is not distinctive of any particular type of motor vehicle body.

closed only from approximately the belt downward. There are two low doors and one fixed cross-seat for two in the forward section. In the rear section there is one fixed cross seat for two or three. Folding seats for two additional passengers are sometimes used. There are two doors in this section and two movable glass windows on each side.

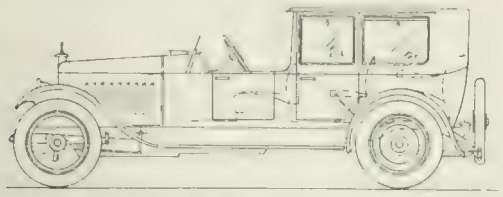


FIG. 50—BROUGHAM

Brougham (Fig. 50)—A body of the same general description as the limousine, except that the non-collapsible roof extends only over that portion of the body that is entirely enclosed.

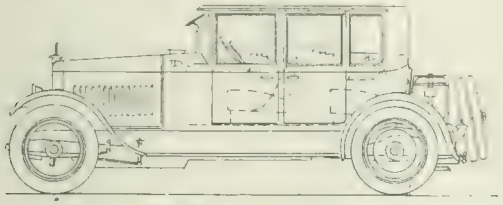


FIG. 51———————

———[18] (Fig. 51)—An enclosed single-compartment body with two fixed cross-seats, close-coupled and allowing the minimum fore-and-aft seating space for four passengers. The conventional body has four doors and there may be movable glass side-windows in the doors only, with solid rear quarters or the quarters may have small movable or fixed windows. There is a luggage compartment at the rear.

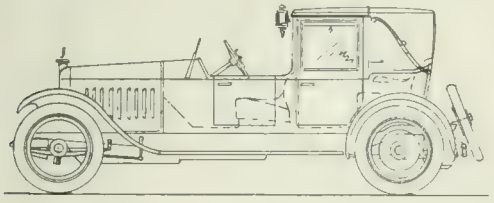


FIG. 52—LANDAULET

Landaulet (Fig. 52)—A body similar in appearance to the brougham, except that the enclosed section is shorter from back to front and the roof is fully collapsible up to the partition at the back of the driver's seat. The body has one fixed cross-seat in the rear section for two or three passengers, two doors made with either flappers or hinged upper parts, and glass windows in the doors only. The rear quarters, back and top are covered with leather or fabric. There are outside joints to support the top.

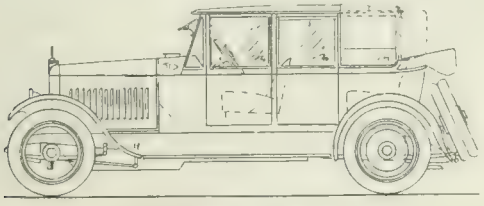


FIG. 53—SEDAN-LANDAULET

Sedan-Landaulet (Fig. 53)—A body of the same general description as the sedan, except that the top back of the rear doors is collapsible. Forward of this point the roof is non-collapsible and the windows are the same in number as in the sedan. The rear quarters, the back above the belt and the roof are covered with leather or fabric.

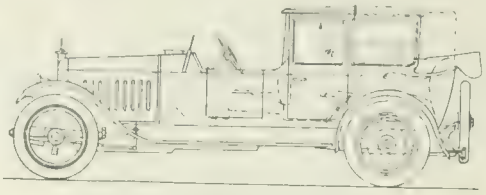


FIG. 54—BROUGHAM-LANDAULET

Brougham-Landaulet (Fig. 54)—A body that bears the same relation to the brougham as the sedan bears to the sedan-landaulet.

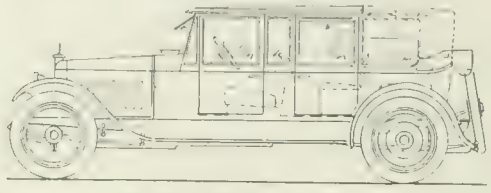


FIG. 55—BERLINE-LANDAULET

Berline-Landaulet (Fig. 55)—A body that bears the same relation to the berline as the sedan-landaulet bears to the sedan.

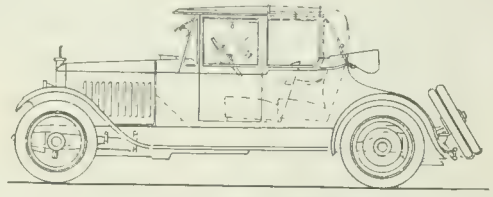


FIG. 56—COUPE LANDAULET

Coupe-Landaulet (Fig. 56)—A body that bears the same relation to the coupe as the sedan-landaulet bears to the sedan.

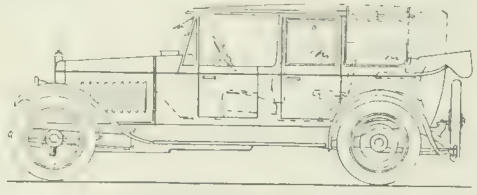


FIG. 57—LIMOUSINE-LANDAULET

Limousine-Landaulet (Fig. 57)—A body that bears the same relation to the limousine as the sedan-landaulet bears to the sedan.

———— *Landaulet*[18]—A body that bears the same relation to the ———— as the sedan-landaulet does to the sedan.

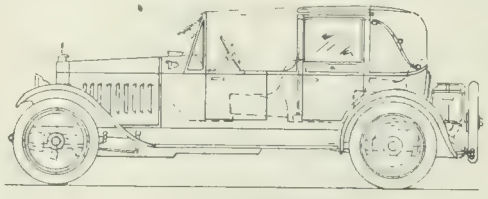


FIG. 58—CABRIOLET

Cabriolet (Fig. 58)—A body similar in appearance to the brougham and having the general characteristics of the landaulet, except that the falling pillar-hinge is set back from the pillar line and shows the curved parting line through the leather. The rear section is therefore longer than that of the landaulet. The body has one fixed cross-seat for two or three and folding seats on the partition for two additional passengers. The

[18] The name for this type of body has not been determined.

doors in the rear section are made with either flappers or hinged upper parts, and there are glass windows in the doors only. The top is fully collapsible, including the partition at the back of the driver's seat. The upper rear quarters, the back and the top are covered with leather or fabric, and in the conventional design the top corners on both the sides and the back, have larger radii than other types of closed bodies. There are outside joints to support the top.

SCREW-THREAD DIVISION REPORT

Pressure-Gage Connections

(Proposed S.A.E. Recommended Practice)

The Screw-Thread Division recommends the adoption as S.A.E. Recommended Practice of the pressure-gage connections given in Fig. 59 and Table 16. The recommendation is the result of investigations by a Subdivision and has been approved by the pressure-gage manufacturers and users.

The recommended ¼-in. diameter tubing is used on the majority of passenger cars, the 5/16-in. tubing on several of the larger high-powered passenger cars, and the ⅜-in. tubing on a large number of motor trucks. The size of aperture recommended is the same for all three sizes of connection as the area of this opening need not vary for different tubing sizes. As the aperture is frequently drilled in a plug that is screwed into the connection, and as plugs fitting a hole tapped with No. 10-32 thread are usually used, the specification of this thread is included in the recommendation. A ⅛-in. pipe-thread connection also is sometimes used, and is recommended as an alternative construction.

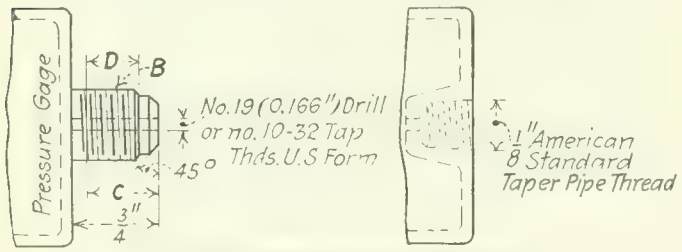


Fig. 59—Pressure-Gage Connections

TABLE 16 –PROPOSED PRESSURE-GAGE CONNECTIONS

Tubing Diameter, in.	B[19]	C Minimum Usable Thread	D Minimum Usable Thread
1/4	7/16 — 20	1/2	11/32
5/16	1/2 — 20	9/16	3/8
3/8	5/8 — 18	5/8	13/32

The construction shown at the right should be used when the construction shown at the left is not provided.

[19] S.A.E. thread. All dimensions in inches.

TIRE AND RIM DIVISION REPORT

Pneumatic Tires and Rims

(Proposed Revision of S.A.E. Standard)

The Tire and Rim Division recommends that the present S.A.E. Standard for Pneumatic Tires and Rims, page G1, S.A.E. Handbook, be revised by eliminating the 32 x 3½, 33 x 4 and 33 x 4½-in. rim sizes and the corresponding regular and oversize tire sizes, and by adding the 30 x 3½-in. straight-side rim and the 31 x 4-in. oversize straight-side tire. The adoption of this proposal will reduce the present standard to five rim sizes and nine tire sizes for passenger cars and an equal number for motor trucks. As it is recognized, however, that the standardization of tires and rims is influenced by other than purely technical considerations, the Division recommends the proposal for adoption as S.A.E. Recommended Practice.

Particular emphasis is laid on the fact that this recommendation is not intended to call for immediate discontinuation of all other tire or rim sizes. Non-standard sizes will of necessity continue in production on a decreasing scale until those automotive vehicles now in service which are equipped with non-standard rims and tires are finally discarded.

A review of the standardization of pneumatic tires shows that the original list of sizes which was first adopted by the Association of Licensed Automobile Manufacturers nearly 15 years ago has been changed at very frequent intervals, additions generally being made until during the latter part of the recent war a definite schedule for eliminating certain sizes by groups at stated intervals of time was approved. The standard, however, instead of becoming more effective, was more or less disregarded by many car and tire manufacturers for use on new equipment. This condition was one of the influences that led to a lack of cooperative effort and the differences of opinion among the groups interested.

As the result of this situation, a conference was held in Cleveland in November 1920 which was attended by tire, rim and automobile manufacturers and at which a resolution was passed that the Society should appoint a special committee representing the National Automobile Chamber of Commerce, the Rubber Association of America and the Society of Automotive Engineers for the purpose of carefully studying the existing conditions and preparing a recommendation which would meet with the approval of the industry and the National organizations representing its various branches.

The Committee thus appointed conferred with the automobile and tire manufacturers and carefully analyzed the situation. Much thought was devoted to coordinating the many interests involved and the proposal now recommended was finally agreed upon, submitted to the Standardization Committee of the Tire Manufacturers' Division of the Rubber Association of America, which approved it, and to the National Automobile Chamber of Commerce. The report is now submitted to the Standards Committee and the Society for approval and adoption in compliance with the regular procedure of the Society.

TABLE 17—PROPOSED S. A. E. TIRE AND RIM RECOMMENDED PRACTICE

Type	Rim Size	Rim Type	Tire Size Regular	Tire Size Oversize	Tire-Seat Diameter
Passenger Car	30x3½	C	30x3½	31x4	23
	30x3½	″	.....	31x4	23
	32x4	″	32x4	33x4½	24
	32x4½	″	32x4½	33x5	23
	34x4½	″	34x4½	35x5	25
Motor Truck	34x5	″	34x5	36x6	24
	36x6	″	36x6	38x7	24
	38x7	″	38x7	40x8	24
	40x8	″	40x8	42x9	24
	44x10	″	44x10	.....	24

All dimensions in inches.

The list of tire and rim sizes revised in accord with the proposal of the Division is given in Table 17. The Division recommends that the proposed list be used by passenger-car and motor-truck designers to select tire sizes for apparatus not yet in production, or at such a

time as a change to a recommended size can be logically made.

It is also recommended that for figuring speedometer gear-ratios and fender and wheel housing clearances, the actual tire widths and outside diameters be measured on the tires to be used.

TRACTOR DIVISION REPORT

Tractor Drawbar Height

(Proposed Revision of S.A.E. Standard)

The Tractor Division recommends that the present S.A.E. Standard for Tractor Drawbar Height, page K40, S.A.E. Handbook, be extended to include the additional dimensions specified in Table 18, as recommended practice for hitching farm-implements to tractors. The present S.A.E. Standard does not differentiate between 12 and 14-in. plows or the number of plows in a gang, nor does it indicate a recommended practice for the location of the tractor hitch with regard to the furrow.

The proposed extension has been submitted to the American Society of Agricultural Engineers and the National Implement & Vehicle Association so that it may be generally adopted as an Agricultural Equipment Standard in pursuance of the arrangement made between the Society of Automotive Engineers and those organizations whereby standards approved by any two of them are known as American Agricultural Equipment Standards.

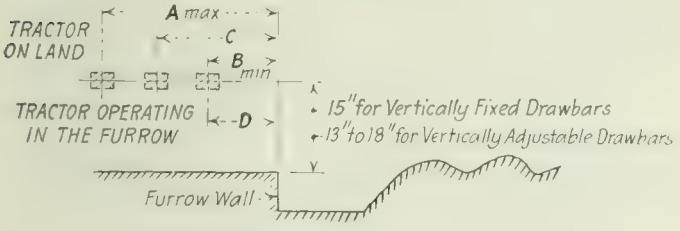


Fig. 60—Tractor Drawbar Height

TABLE 18—PROPOSED TRACTOR DRAWBAR HEIGHTS

Plow	Two-Bottom		Three-Bottom		Four-Bottom	
	12-in.	14-in.	12-in.	14-in.	12-in.	14-in.
A	30	30	32	32	40	40
B	15	15	20	20	24	24
C	17	20	23	26	28	32
D	15	15	20	20	24	24

A—Maximum position for good operation, ordinarily the best possible position.

B—Minimum position for good operation with the tractor operating on the land.

C—Proper or best average position when the tractor operates on the land.

D—Minimum hitch position when the tractor operates in the furrow.

TRANSMISSION DIVISION REPORT

Transmission Tire-Pump Mountings

(Proposed Revision of S.A.E. Standard)

The Transmission Division was requested to revise the present S.A.E. Standard for tire-pump mountings of the transmission type, page E1, S.A.E. Handbook, by cutting back the inside edges of the large-type mounting pad, so as to allow more clearance for the idler-pinion carrier.

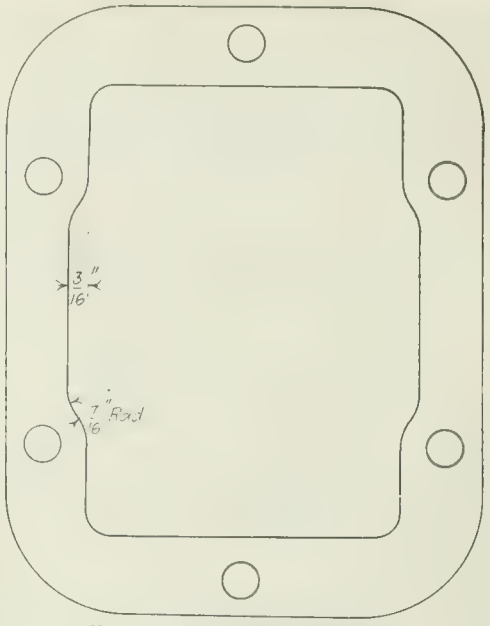


Fig. 61—Tire-Pump Mounting

It was stated that this change had already been put into practice and, as no changes in the dimensions of the present standard are involved, the Transmission recommends that the revision be made as shown in Fig. 61.

Clutch Facings

(Proposed S.A.E. Recommended Practice)

Standardization of clutch facings was proposed to and has been carefully considered by the Transmission Division to reduce the number of sizes to a practical minimum and to secure the resulting economies in the manufacturing and, to a large extent, the service branches of the automotive industry.

TABLE 19—PROPOSED MULTIPLE-DISC CLUTCH-FACING SIZES

Outside Diameter, in.	Inside Diameter, in.	Thickness, in.	Tolerances, in.	
			Outside Diameter	Inside Diameter
$8\frac{1}{2}$	6, $6\frac{1}{4}$, $6\frac{1}{2}$	$\frac{5}{32} \pm 0.005$ for all sizes	Woven $+0.000$ $-\frac{1}{16}$	Woven $+\frac{1}{16}$ -0.000
$8\frac{1}{4}$	6, $6\frac{1}{4}$, $6\frac{1}{2}$		Molded $+0.000$ $-\frac{1}{32}$	Molded $+\frac{1}{32}$ -0.000
8	$5\frac{3}{4}$, 6, $6\frac{1}{4}$			

A careful study was made of existing practice by a Subdivision and a tentative report submitted for the consideration of the Division and the clutch manufacturers. This report was published on page 285 of the

TABLE 20—PROPOSED SINGLE-PLATE CLUTCH-FACING SIZES

Size	Type	Outside Diameter, in.	Inside Diameter, in.	Thickness, in.	Tolerances, in.	
					Outside Diameter	Inside Diameter
8	Woven	$7\frac{7}{8}$	$5\frac{3}{8}$	$1\frac{5}{64}$ or $\frac{5}{32} \pm 0.005$ for all sizes	Woven $+0.000$ $-\frac{1}{16}$	Woven $+\frac{1}{16}$ -0.000
	Molded	8				
10	Woven	$9\frac{7}{8}$	$6\frac{3}{4}$		Molded $+0.000$ $-\frac{1}{32}$	Molded $+\frac{1}{32}$ -0.000
	Molded	10				
12	Woven	$11\frac{7}{8}$	$8\frac{1}{4}$			
	Molded	12				

October issue of THE JOURNAL. It is, of course, not expected that clutch manufacturers will revise their clutch designs to take the proposed clutch-facings before they can economically and conveniently do so.

The facing manufacturers have indicated their desire for such a standard as is proposed and the Transmission Division now recommends for adoption as S.A.E. Recommended Practice the clutch-facing sizes listed in Tables 19 and 20.

The Division is giving consideration to clutch facings with the intention of standardizing rivets and their location. This phase of the work will require much further study.

TRUCK DIVISION REPORT

THREE-JOINT PROPELLER-SHAFTS

(Proposed S.A.E. Recommended Practice)

The use of long-wheelbase motor trucks requiring an additional support at or near the center of the propeller-shaft has, during the last few years, resulted in a great number of different designs of front-shaft rear shaft-end on which the center bearing is mounted.

It being believed that the three-joint propeller-shaft has been in use long enough to permit standardizing the front-shaft rear shaft-ends, the Society was requested to undertake the work. The subject was assigned to the Truck Division and a Subdivision consisting of J. R. Coleman, chairman, H. B. Knap and J. W. B. Pearce was appointed to obtain information on present practice and to prepare a tentative report.

A progress report was submitted by the Subdivision at the April 1921 meeting of the Truck Division which indicated that the adoption of a standard for the front-shaft rear shaft-ends was desirable and would result in considerable economy in manufacturing, assembling and servicing.

After holding several meetings the Subdivision submitted a final report on Oct. 13 which was favorably acted upon by the Truck Division by letter ballot. The report follows and is submitted for adoption as S.A.E. Recommended Practice.

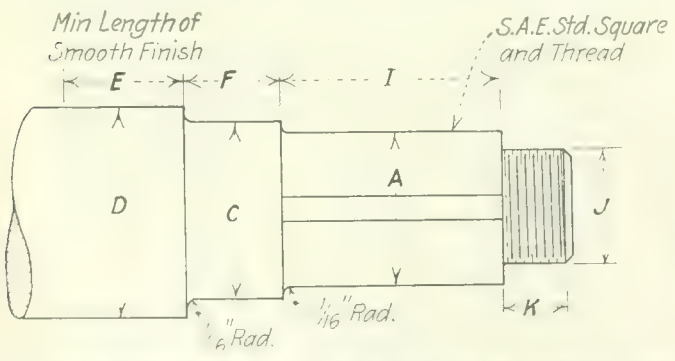


FIG. 62—PROPELLER SHAFT FOR USE WHERE THE REAR END OF THE FRONT SHAFT IS SQUARE

Nominal Diameter	A	C	D	E	F	I	J[1]	K[2]
1¼	1.250 1.245	1.378 1.377	1 11/16	1	49/64	1 1/16	1-20	11/16
1⅜	1.375 1.370	1.575 1.574	1⅞	1 1/16	33/32	1 13/16	1-20	11/16
1½	1.500 1.495	1.772 1.771	2 3/16	1⅛	57/64	1 15/16	1-20	11/16
1¾	1.750 1.745	1.968 1.967	2 7/16	1 3/16	1	2 5/16	1¼-18	13/16
2	2.000 1.995	2.166 2.165	2 7/16	1¼	1 5/64	2 13/16	1¼-18	13/16

[1] All dimensions in inches.
[2] As specified in the S.A.E. Standard for Square Fittings, page C12, S.A.E. HANDBOOK.

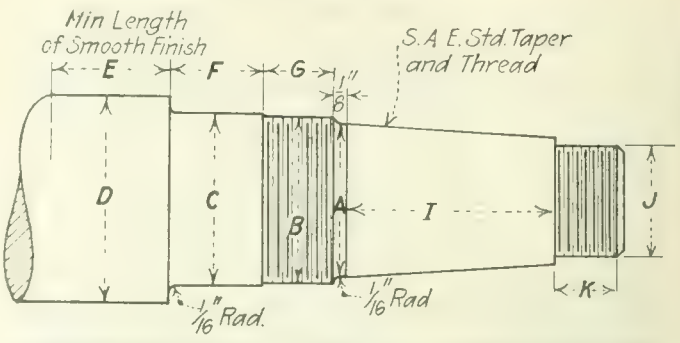


FIG. 63—PROPELLER SHAFT WHERE THE REAR END OF THE FRONT SHAFT IS TAPERED

TAPER PER FOOT 1.500 ± 0.005 IN.

Nominal Diameter	A	B-Diameter and Thread	C	D	E	F	G	I[23]	J[23]	K[23]
1¼	1.251 1.249	1⅛-18	1.378 1.377	1 11/16	1	49/64	5/8	1 3/8	1-20	11/16
1⅜	1.376 1.374	1 1/4-18	1.575 1.574	1⅞	1 1/16	33/32	5/8	1 7/8	1-20	11/16
1½	1.501 1.499	1⅜-16	1.772 1.771	2 3/16	1⅛	57/64	3/4	1 7/8	1-20	11/16
1¾	1.751 1.749	1⅝-16	1.968 1.967	2 7/16	1 3/16	1	3/4	2 1/8	1¼-18	13/16
2	2.001 1.999	1⅞-16	2.166 2.165	2 7/16	1¼	1 5/64	3/4	2 3/8	1¼-18	13/16

[22] All dimensions in inches.
[23] As specified in the S.A.E. Standard for Taper Fittings, page C14, S.A.E. HANDBOOK.

Self-aligning bearings provided for taking radial loads only shall be used for supporting the rear shaft-end of the front shaft of motor-truck, three-joint propeller-shafts. All thrust loads shall be carried by the transmission and the rear axle.

The bearing shall be clamped to the shaft in accord with good bearing-mounting practice.

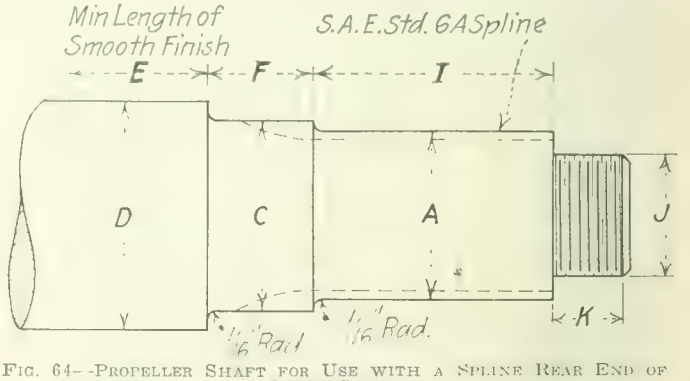


FIG. 64—PROPELLER SHAFT FOR USE WITH A SPLINE REAR END OF FRONT SHAFT

Nominal Diameter	A	C	D	E	F	I[25]	J[25]	K[25]
1¼	1.250 1.245	1.378 1.377	1 11/16	1	49/64	1 1/16	1-20	11/16
1⅜	1.375 1.370	1.575 1.574	1⅞	1 1/16	33/32	1 13/16	1-20	11/16
1½	1.500 1.495	1.772 1.771	2 3/16	1⅛	57/64	1 15/16	1-20	11/16
1¾	1.750 1.749	1.968 1.967	2 7/16	1 3/16	1	2 5/16	1¼-18	13/16
2	2.000 1.995	2.166 2.165	2 7/16	1¼	1 5/64	2 13/16	1¼-18	13/16

Spline fitting dimensions shall be as specified in the S.A.E. Standard for 6A spline fittings, page C18, S.A.E. HANDBOOK.

[24] All dimensions in inches.
[25] As specified in the S.A.E. Standard for Taper Fittings, page C14, S.A.E. HANDBOOK.

Shaft-ends shall be in accord with the S.A.E. Standards for square, taper or spline fittings, pages C12, C14 and C18, S.A.E. HANDBOOK.

The following S.A.E. Standard annular ball bearings of the medium series, page C28, S.A.E. HANDBOOK, shall be used on the shaft-ends recommended:

Shaft-End, In.	Bearing, No.
1¼	307
1⅜	308
1½	309
1¾	310
2	311

The shaft-end dimensions given in Figs. 62, 63 and 64 shall be used.

STILL MARINE ENGINE

THE Still engine built by Scotts' Shipbuilding & Engineering Co., Ltd., Greenlock, is, we understand, the largest of the type so far constructed. It is of the slow running marine type suitable for the merchant service.

As is generally known, the Still oil engine is a combination of an oil and a steam engine. The main source of power is oil consumed within a cylinder for the down-stroke, operating in this particular machine on the two-cycle principle, while steam forms a supplementary source of power, being used for the up-stroke. The primary aim of the design is to reduce heat losses to a practical minimum. This is accomplished by raising steam by (*a*) heat taken up by the water circulating in the cylinder jacket under working steam pressure and (*b*) heat recovered from the exhaust gases by regenerators and feed-water heaters. All of the first heat goes to form steam. In the second scheme water is evaporated in the regenerators and the feed water is raised to boiler temperature in the heaters.

To carry this out in practice, it is necessary to provide certain steam plant, and steam inlet and exhaust-valves for the cylinders. There are, however, certain compensating advantages, and the most marked of these is that no compressed air is required for starting and maneuvering, because under these conditions, the engine is really a steam engine with the flexibility always associated with that class of machine. This makes the engine very easy to handle and, of course, allows it to run at very low speeds. Another direct result of this combination is that a low compression-pressure can be used with absolute certainty of "firing," the reason being that the cylinder walls are kept at steam temperature by water circulating in the jacket from the regenerator. During compression the air charge picks up heat from the walls instead of being cooled by them for the greater portion of the stroke, as occurs in the Diesel engine. The relatively low compression-pressure enables lighter scantlings to be used, or alternatively provides a larger margin of safety, as the maximum pressure possible in the cylinder is a function of the compression-pressure. It further provides a useful margin for any loss of pressure in service, as the pressure used in practice in this engine, although considerably below that of the Diesel engine practice, is well above the minimum pressure that will produce the temperature required to insure combustion. In the Scotts engine, we understand the normal compression-pressure used is about 300 lb. per sq. in. The engine is a single-cylinder unit of 22-in. diameter and 36-in. stroke. Scavenging air is supplied by a motor-driven Reavell turbo blower. This discharges into a large tank to minimize the fluctuations of pressure, whence it passes to the cylinder by way of the bedplate and columns.

The exhaust gases pass from the engine to a regenerator, in this case a small Cochran boiler, set above the level of the combustion cylinder jackets. The gases finally pass through a feed-water heater on their way to the atmosphere. Steam is taken from the regenerator to the engine and expanded in two stages to the condenser. To effect this, owing to the experimental engine having only a single cylinder, it has been necessary to provide a small auxiliary steam cylinder. This forms the high-pressure cylinder and the lower end of the main cylinder serves as the low-pressure cylinder, whence the steam passes to the condenser. Compounding in, say, a six-cylinder engine would be secured by using the lower ends of two combustion cylinders as high-pressure steam cylinders and those of the other four similar cylinders as low-pressure steam cylinders.

The combustion cylinder jacket, as has been stated, is kept under steam pressure and temperature by a circulation of water from the regenerator through the jacket and back again; no pump is necessary, as the circulation is a natural thermal one. Thus, when the engine is cold and the burner under the regenerator is lighted, the water begins to circulate from the regenerator to the cylinder jacket, heating the latter gradually until the desired steam temperature and pressure are reached. When the engine is running and the regenerator burner has been shut off, the circulation reverses and takes place from the cylinder jacket to the regenerator because of the heat added to the jacket water through the cylinder liner, and the steam produced finds its way by the pipes provided to the regenerator. The steam and exhaust-valves are of the piston type, and are operated by oil under pressure.

All the pumps necessary for the engine, except the scavenging blower, the forced-lubrication pump, valve-gear oil-pump, circulating pump, air-pump and feed-pump are driven from the main engine-shaft. A complete system of oil-measuring and water-measuring tanks is provided. The latter are placed in the space beneath the regenerator.

Special provision is made in the design of the engine for expansion and contraction due to heat, the combustion cylinder being held by a joint at its lower end only, thus being free to expand upward as the temperature rises. The steam end of the cylinder is also free to expand. The cylinder has no cover in the ordinary sense of the word, and there is an entire absence of cams and rods about the cylinder, even the fuel-valve operating automatically by the action of the fuel-pump. The engine works on the solid-injection principle, that is to say, no air is used to atomize the oil during injection into the cylinder.

The following are the extracts from reports on the engine made by some French engineers representing commercial interests:

> The fuel-consumption figures . . . are extremely low. One can estimate that with a good four-cycle Diesel engine, the quantity of oil consumed would have been at least 10 per cent and with a two-stroke engine 20 per cent higher. It is further necessary to take into account the point that a provisional single-cylinder installation causes losses in efficiency that would not be found in a complete installation intended for normal service. In particular the high-pressure steam cylinder was isolated from the group and did not completely benefit by the favorable conditions in which the steam expands in a Still cylinder. The pressure pump for the oil required to operate the steam valve-gear was driven by a small auxiliary engine with a high steam consumption, due to the engine-driven pump being temporarily out of action. It is justifiable therefore to estimate that in a normal installation the fuel consumption at equal power would be still further reduced.
>
> . . . . The Still engine is a machine of the greatest interest which seems able to render great service in all cases where it is necessary to obtain great facility of maneuver, powerful starting torque and large variation of load.
>
> During the full-load trial the power was 343 b. hp., from which has to be deducted 14.1 b. hp. absorbed by the scavenging pump, leaving 329 b. hp. available at the engine-shaft. The fuel consumption was 123.4 lb. per hr., that is to say, a consumption of 0.360 lb. per b. hp-hr.—*Engineering* (London).

DOMESTIC PURCHASING-POWER

EXPORTS of wheat, cotton, copper and other raw materials have placed the United States in a dominant position in the world commodity markets. Natural resources and modern methods of production have enabled the United States to produce more commodities of those classes than the domestic market could consume at prices enabling the American producer to meet competitors in the international markets.

Through the century preceding 1914, the countries of northwestern Europe had gradually attained a similar dominance in the international market for manufactured goods. In the beginning this was the result of an historic superiority in skill of production and distribution, together with the early development of the use of steam power. Countries less advanced industrially were anxious to exchange food and other raw materials for the manufactures of Europe.

This specialization has resulted in the development of a population in the leading countries of northwestern Europe far in excess of the ability of their soils to feed according to the European standard of life, and capable of producing manufactured goods beyond the power of their home markets to consume. Japan likewise has an excess population that is rapidly gaining industrial skill. If these countries cannot market their excess manufactures, the population must reduce its standard of life or millions must emigrate. Sheer necessity has forced manufacturers in these countries into the struggle for remote markets, and the pressure of a skilled population enables them to sell at prices that determine the world markets for many classes of manufactured products. This sharp competition does not preclude competition by the United States in manufactures, but it does determine the directions in which American selling efforts can be most favorably expended.

The population of the United States is now about equal to that of the United Kingdom and Germany combined. It exceeds by probably 40,000,000 the population of all of South America. The standard of life of the American people is equalled only by that of the people of Canada and Australia, the combined population of which is only 15,000,000 or 14 per cent of that of the United States.

The United States is not sufficiently dependent on foreign markets to justify the belief that business recovery in this country must await recovery abroad. At prices determined in the international markets American raw materials for export will find an outlet. By far the greater part of the entire manufactured product of the country has always been sold at home and as price adjustments are completed the domestic market will again absorb the major portion of our production.

It is true that the buying power of the domestic consumer has been much curtailed. High taxes have cut heavily into the sums that might have been spent for clothing, furniture and all those articles that have made the life of the average American family so rich in comforts and luxuries. Declines in the prices of agricultural products and widespread unemployment have reduced the buying ability of a large part of the population, and high rents, high fuel costs and high transportation charges have operated in the same direction. Many of these items represent temporary maladjustment, and their effects will lessen gradually and tend to disappear eventually.

Except in a few areas the widespread and severe unemployment has not materially reduced savings bank deposits, while in some localities steady gains in such deposits have been made throughout the period of depression. Sharp curtailment of income has impressed the necessity of saving on many who failed to take advantage of temporarily higher incomes. Economy has become fashionable. The time has passed when any considerable section of the public will buy regardless of cost. Sales policies based on a belief that buying can be stimulated by artificial methods and that another era of extravagant buying can be induced under present conditions will not succeed.

The American consumer, however, has suffered no material permanent curtailment of purchasing power. Goods of all kinds, in large volume, can be sold in every part of the United States today, if they are staple in character, and if prices are such as to represent real values to conservative purchasers. As the volume of goods thus sold expands, employment will automatically increase and in turn, new purchasing power will develop. The domestic market assures the American producer of an outlet.—*Commerce Monthly.*

STANDARDIZATION AS AN AID TO SIMPLIFICATION

SIMPLIFICATION, as defined in the standard dictionaries, is the act or process of rendering simple or more simple, or making less complex or difficult.

Standardization is defined as the act or process of conforming to any measure of extent, quantity, quality, or value established by law or by general usage and consent.

Thus the procedure of a company in limiting its types and sizes of product to the lowest number possible is simplification, not standardization.

Standardized products conform to those standards established by general usage and consent; in the automotive industry, to standards approved by the Society of Automotive Engineers, or the Government; the former because S. A. E. Standards have been based on usage and have met with general consent as evidenced by the letter ballots of the Society members, and the latter because the Government has legalized certain generally used standards such as standards of time, weight and measure.

To obtain the greatest simplification, standardization must be carried to the greatest possible extent. Simplification is a plant problem; standardization a National problem. Simplification can be obtained only by the cooperation of department heads of a company; standardization by the cooperation of executives and engineers in general.

PRODUCTION OF LIQUID AIR

IN the plant for liquefying air by the Hampson process, installed at the Bureau of Standards, a four-stage steam-driven compressor delivers air at room temperature and under a pressure of approximately 3000 lb. per sq. in.; this air then passes through an oil and water trap and a purifying train containing reagents that remove the carbon dioxide and water vapor. The air thus compressed and purified is delivered to the liquefier, in which after passing through a coil of copper tubing, the air is allowed to expand freely to approximately atmospheric pressure. Where this drop in pressure takes place, there is a corresponding drop in the temperature of the air. The expanded air before leaving the liquefier circulates around the copper coil that contains the sompressed air, thus cooling it so that in continuous operation a cycle of progressive cooling is maintained until the temperature ultimately reaches the liquefying point. The liquefier is constructed so that the air that is condensed is delivered into a receiving vessel. The gaseous air exhausted from the liquefier is returned to the intake of the compressor for succeeding cycles because it has been purified and when used repeatedly will be found to be very much less exhausting on the purifying reagents that are employed to remove all traces of carbon dioxide and water vapor.—From Bureau of Standards Technical News Bulletin No. 55.

Automotive-Engineering Research

By H. C. Dickinson[1] Detroit Section Paper

EMPHASIS is placed upon the propriety of applying the term "research" only to such lines of investigation as are capable of yielding general results that can be utilized by other than the original observers. The distinction between research thus defined and much else that can be classed correctly as research according to its ditionary definition is explained.

In stating the purpose and aim of the Research Department of the Society, the divisions of the thought include research personnel requirements, the support of research, the importance of research, problems suitable for research in the industrial, educational and independent laboratories, the general research program and the avoidance of duplication of research work.

The fuel and the highway problems are enlarged upon as insistently demanding immediate research information and a strong recommendation is made that all members interested in research reread and study the papers covering these subjects that have been published in The Journal, reference being made to the accompanying bibliographical list.

RESEARCH is defined in the dictionary as being "a diligent search for information," but this fails to assist us to any great degree in arriving at a definite understanding of exactly what we mean by automotive-engineering research. The term research has been applied correctly, of late, to many fields of endeavor that are not at present within the scope of the engineering research department of the Society of Automotive Engineers. For instance, the modern department of sales research, however important and interesting, must be omitted for the present. One definite limitation that physicists, chemists, research engineers and all dyed-in-the-wool scientists like to stipulate in connection with the term research, whether correctly or not, is that the term shall apply only to such lines of investigation as are capable of yielding general results, that is results that can be put into the form of general laws, equations, charts, tables or curves, and utilized by other than the original observers.

The distinction between research thus defined and much else that can be classed correctly as research according to the dictionary can be illustrated. For instance, the trial of an individual design of manifold, the testing of a single newly designed engine, road trials for the development of a new chassis model, ordinarily would not constitute research in this sense. If, however, the device under test were one of a series differing only in some definite particular, the series of tests, together with the comparison of their results, might constitute such research. Thus, tests of a series of manifolds differing by definite amounts in diameter, heated area or temperature, or tests of a series of engines differing in a single particular, such as the valve area or the shape of the combustion-chamber, might lead to general conclusions regarding the effect of these particular changes in design. This series of tests would be classed properly as research, according to this definition, when the results were put in such form that they could be applied to future design. In using the term "research" in this paper, its meaning is limited to the foregoing conception of the term, since this will assist in drawing a line of distinction which is essential to a correct understanding of the aims of the Research Department.

Research as here defined includes explorational and intensive research, as the words have been used in previous discussions of the subject, but it omits the major part of what has been termed "developmental research." The last named is recognized as being primarily a function of the individual engineer and the industrial laboratory. By far the largest part of the work of all the laboratories connected with the industry is of this nature and, as such, it is recognized by the department as being essentially confidential. However, it is coming to be more and more generally recognized that there is much more to be gained than lost through a free interchange of all research information, although we regret, sometimes, to find this more as an abstraction than as a course of action. The Research Department, therefore, will confine its efforts to explorational and intensive fundamental research. Much work of this nature that is in progress in the industrial laboratories will be of interest to the department, and it is hoped that much more such work will be undertaken in the future; but we will not concern ourselves with the major part of the work of these laboratories, which is development work.

Research Personnel Requirements

The true research man is "born, not made." To be a success in any large sense, he must have the advantage of the equivalent of the best scholastic training; otherwise he cannot master the tools of research, which are the correct use of engineering instruments, and the making of precise laboratory measurements and mathematical analyses of results in the light of known physical and chemical facts and laws. He must always know the why of any observed fact. Without the use of these tools, often he will be led to irrational conclusions and costly errors.

These particular requirements appear less important in the experimental development laboratory. Here the *why* is of less importance than the individual fact, and the correctness of the fact must be checked and rechecked by trial. However, an unbelievable amount of time and effort is wasted in the trial of expedients that a more careful application of the fundamental laws of physics and chemistry would show at a glance are based on incorrect assumptions. This fact was startlingly illustrated during the war when thousands of inventions of every conceivable sort were presented for the consideration of the Government. It is safe to say that at least 90 per cent of these proposals showed such obvious and fatal errors in fundamental physical and chemical principles that they could be condemned absolutely, at once; most of them could be condemned equally well on practical grounds, but one's judgment as to practical possibilities is by no means so safe a guide. Many things that look impractical do actually work but, so far as we know, nothing works that violates the law of the conservation of energy, the second law of thermodynamics, Newton's laws of motion, or any other of

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several hundred such principles. Successful engineering research and economical development work require men with a peculiar combination of broad fundamental knowledge and sound commonsense, to which is added the enthusiasm of the typical inventor with his typical shortcomings eliminated.

The Support of Research

The two main incentives that actuate the research man are a thirst for knowledge and the hope of economic progress. So far as the research worker himself is concerned, one can almost neglect the second incentive. A desire for knowledge for its own sake is almost the sole incentive of the individual who will devote his life to fundamental research. If the appeal of commercial success is strong, usually he will drift into invention or development where his research training will make for greater returns in money. However, the most common incentive for the organization and continued support of research laboratories or of any systematic research program is necessarily the commercial. In fact, this is almost the only one if we except some of the educational laboratories that have been endowed purely for the sake of the advancement of science. Thus, almost every research laboratory, particularly the industrial ones, presents a constant conflict between two viewpoints that are somewhat incompatible. The true research-worker is interested in securing facts and will not be satisfied until his results are complete. Moreover, every problem he undertakes presents to him numerous side-lines that are of absorbing interest. If given his own way, he will either carry through his problem to a final conclusion or switch to some side-line of greater interest, according to his temperament, unless he is endowed with unusual self-control. On the other hand, the director of the laboratory or the capitalist who finances it, will, as soon as some fact of apparent commercial value is developed, recommend dropping the research and developing something useful, unless endowed with unusual patience and foresight. A happy medium between the two viewpoints is difficult to attain; but a real compromise is necessary since both viewpoints are important and neither side can be neglected. I believe that the financial manager is coming more and more to realize that the search for knowledge affords the basis for all fundamental economic development in the long run.

Importance of Research

The extent to which scientific knowledge has preceded and formed the necessary basis of later industrial development is remarkable. For instance, practically all phases of the electrical industry owe their inception and development to the results of scientific researches, some of them antedating their application by many years. Faraday, Maxwell, Kelvin and Helmholtz, who laid the foundation for our present knowledge of this subject, probably had not the slightest idea of any possible industrial application of most of their results. Perhaps it is for this reason that the electrical industry has been the first to recognize the importance of the research laboratory and, particularly, the importance of giving to research men a rather free hand in prosecuting researches that have no obvious commercial application. In general, the profits that have accrued from the application of the results of such researches alone probably have exceeded by far the cost of all research supported by this industry.

In the development of the automotive industry in this Country, the field for research has been somewhat less apparent. The few elementary scientific facts that were essential to the origin of the automobile engine were largely forgotten in the course of its experimental development. Other features of design were more the result of development than of fundamental research, as carried on in this Country at least. It has come about therefore that, up to within the past few years, the United States, which has shown by far the greatest industrial development in the automotive line, has contributed comparatively little to the sum of automotive research. The work of British and German experimenters had to serve the needs of our own engineers, even though it was entirely inadequate for these needs. The reasons for this are perhaps more or less obvious. The industry here has been in an unusually favorable situation. It has been more important to manufacture than to improve designs in the direction of economy and efficiency. Compared with the situation in Europe, there has not been the same kind of competition in the details of design, with correspondingly less intense interest in this subject. I believe we can say without question that this period is past, or at least that the conditions have changed decidedly. Considering the various phases of the fuel problem and the general situation with regard to the distribution of automotive appliances, it seems that the engineer must hereafter turn his attention somewhat more to the perfection of details that will obtain fuel economy. This perfection of details necessitates the application of fundamental research results.

A general awakening to the need of research has occurred within the past few years among members of the Society. Its importance has been so ably presented in recent papers and discussions that it is hardly necessary to emphasize this phase of the subject further. We are now awake to the need and, once awakened, the United States will not lag behind. In fact, perhaps a warning is needed in that, while the possibilities of research hardly can be overestimated, the realization of these possibilities in terms of industrial results rests with the engineers in charge of design and development. No matter how many and how able the research engineers are, or how important their conclusions are, these conclusions and their result will be of value only insofar as they are embodied in successful design. Whatever the Research Department of the Society may do, it cannot replace the thought of the individual designer.

Aims of the Research Department

In general, the object of the Research Department is to secure from all possible sources, through concentrated effort, more and better fundamental technical information for the use of the members of the Society, and to make this information more easily available. The distribution of information can be accomplished in several ways. It is hoped from time to time to publish discussions in The Journal of some of the more important general problems, together with references to all sources where research information can be found. By becoming familiar with the work in progress at the various laboratories, it is hoped to secure more general interchanges of information directly between engineers working along the same lines. However, while the department will serve a useful purpose as a convenience in collecting and spreading information, its main and ultimate object will not be attained until the automotive-research facilities of the Country shall have met adequately the needs of the automotive industry. We often

learn of work being undertaken in various laboratories that has been done elsewhere. If the results of previous work have been published, there is very little excuse for repeating it, at least without careful study. In case the previous work has not been published, it can be made of value only by establishing some means of securing a better interchange of information as to what research is in progress at the various laboratories.

The question of whether the department expects to establish a laboratory of its own has been asked many times. This can be answered definitely in the negative, for the time being at least. The reasons are rather obvious. First, establishing a laboratory on an adequate basis would involve a very large expenditure. This fact alone, however, should not prevent planning for such a laboratory in the near future if there were not other and better reasons for not doing so. Fundamental research is in the last analysis almost entirely a question of men rather than of equipment. Many of the most important scientific results have been obtained almost without any laboratory equipment worthy of the name. A study of the research situation in the various laboratories leads to the conclusion that these are even now sadly undermanned, particularly with men of real ability. Establishing a new laboratory could not increase the supply of first-grade research men; it would have to be manned at the expense of existing institutions, and the net result probably would not be increased research. It appears, therefore, that the department can devote its efforts most profitably to assisting existing research laboratories. These laboratories are of three classes, industrial, educational and independent. They occupy altogether different positions in regard to research, and any general plan of research must take account of these differences.

Industrial Laboratories

It is recognized that the prime object of the industrial laboratories, those directly connected with the various manufacturing companies, must always be developmental research. But we hope that there will be accomplished in connection with this an ever-increasing amount of fundamental research work that can be made of general value; such work as deals with general principles rather than with specific questions of design. An excellent illustration of this point is found in A. L. Nelson's paper on the Fuel Problem in Relation to Engineering Viewpoint. While Mr. Nelson's work obviously was undertaken as a development problem, it was handled and the results were analyzed in such a way as to be of utmost general interest and importance. Although it may not seem always permissible to make public so much of the development side of a problem as in this instance, there is without question a very large fund of purely general research data buried in the records of the various automotive laboratories which would be of inestimable value to other members of the Society if it were resurrected and analyzed by the men who have done the work.

It is a very common experience to find one laboratory undertaking a research intended to cover some problem that has been carefully covered elsewhere, although no record of it is available. It is one of the aims of the Research Department to secure the publication or at least a record of such non-confidential general results, so far as possible, and to act as a clearing-house of information on research problems of this character.

The greatest source of scientific research has always been the various educational institutions, unless we revert to the time when research work was done in the monasteries. While this probably is true still, there is no doubt whatever that of late the relative contribution of the schools to research has decreased markedly. Although this may mean that the industrial and various other laboratories, such as those of the Government, have shown a decided increase in number and output, this is a sad state of affairs. Why should not the schools grow and keep pace with other lines of development? The schools are the only sources for the development of research men for the other laboratories.

Industrial Research and the Colleges

The number of students and graduates from the schools has not measurably kept pace with the development of industrial research in outside laboratories. In fact, with some notable exceptions, the amount of instruction and the number of graduates have been increased at the expense of research. In addition, the industrial and other laboratories also have increased at the expense of the research departments of the schools by withdrawing some of the best men. This is a fatal mistake if industry is to continue to progress along scientific lines. Without competent teachers who have the spirit and ability for research, there will be no future supply of graduates with this spirit and ability; and without new personnel neither sound fundamental research nor effective development can proceed.

The many reasons for the present state of affairs are for the most part attributable to conditions beyond the control of any single group of interests. The prime duty of the schools is necessarily teaching and too often this is interpreted to mean turning out graduates. When the number of students increases without a corresponding increase in income to pay teachers, the work of formal instruction takes precedence and research languishes. But, unless the instruction of an engineering or scientific course includes the contact of the student with research men and research methods, there is small chance that he will become a research man himself. Indeed, active and high-grade research in the university and technical school is absolutely essential to the training of men to fill positions in the automotive industrial laboratories. Those in direct charge of our educational laboratories appreciate this most keenly but, mainly, they find it impossible to change conditions. More time for research on the part of teachers, closer contact with the automotive industry so that they will choose the most important problems, and more active moral and financial support from the industry and from the governing boards of the various schools, would improve the situation. An effective effort to maintain the proper relation between research and formal instruction is being made in some universities. The members of the Society can assist along these lines.

To prevent the too great depletion of the educational staffs by the transfer of competent men to industrial laboratories appears more difficult. As the latter have grown in number and importance there has been competition for the best research men, necessarily. The schools cannot compete on the basis of salaries alone and were it not for certain very attractive privileges afforded by the schools, such as freedom from industrial pressure, independence in the publication of results and the personal recognition accorded to a professor, it is doubtful whether there would be any competent research men left in the teaching profession. Even the attractive features of the teaching profession are being extended more and more to industrial-research men. Fortunately, however, there are enough teachers to whom

pure science and unhampered freedom appeal to maintain some of our laboratories on an effective basis.

Research Problems for the Educational Laboratories

The educational laboratory has its own class of research problems. Experimental development, on the one hand, is out of its field and should be discouraged. The first object is to teach principles and methods, not details. On the other hand, problems of very great magnitude, requiring much equipment and years of consistent work, are out of the question except in a few favored institutions, because of the transient character of the staff of student assistants or research fellows that must be depended upon. Between these two extremes, however, is included the major field of industrial or engineering-research problems. For the most part the various laboratories are rather well supplied with problems but, from some institutions where new facilities or new men have become available, there have come requests for suggestions as to problems or general lines of work that might be taken up with advantage. It seems that here is a splendid opportunity for better use of the educational laboratories by the automotive industry. The custom of farming out individual research problems has been followed to some extent by some companies, but there is room for much more of it. The Research Department stands ready to offer any possible assistance in securing greater cooperation of this kind.

Duplication of Research

Much caustic criticism has been offered recently regarding duplication of research. Research is always a matter of duplication and repetition, since no physical fact is ever established except through repeated observation. The individual experimenter must repeat his results many times and, even so, we usually demand several repetitions by independent observers before we are satisfied. One well known scientist has remarked that the mere fact that a phenomenon is repeated 1,000,000 times is no proof whatever that it will be repeated again; that is certainly true unless there is some fundamental law back of it. Hence, much apparent duplication is not only desirable but necessary; but this applies to intelligent duplication only. Not much is to be gained by having several different laboratories working on the same problem, unless each one knows something about what the others are doing. Unnecessary duplication of this kind should be avoided so far as possible, particularly among the educational laboratories.

Since the results of most research are not available in print for months or perhaps years after the work is begun, the most promising means of preventing unnecessary repetition is some central clearing-house for work proposed and in progress. This function the Research Department hopes to fulfill.

General Research Program

One of the important objects of the Research Department is to assist in the development of a more systematic program of research throughout the automotive industry. The formulation of such a program is too much of a problem to be solved for some time to come. It must be built up little by little with the cooperation of all the members of the Society. I hesitate therefore to say very much on this topic. There are, however, two broad general problems that are brought to attention at once by their importance and the insistent demand for immediate information. These are the fuel problem and the highway problem. The former has been occupying our attention to an increasing extent for two or three years. More than 30 technical papers have appeared in The Journal alone since Jan. 1, 1919, dealing with some phase of the fuel situation, and the majority of them represent independent research. Most of them are valuable and important papers. Also, a considerable number of papers on different phases of the highway problem have been printed in The Journal during this same period. A bibliographical list covering both of these subjects is appended. It is earnestly recommended that all members who are interested in research reread and study these papers carefully, as they represent the latest thought and research and indicate the present status of the problems; having in mind the particular phases of the subjects that have the strongest appeal in connection with their own personal activities. Attention is called also to the wealth of information contained in the articles quoted from other sources in these issues of The Journal.

These papers and articles probably represent more suggested new problems than completed ones. For instance, a very important problem has to do with the relation between the end-point or the volatility of fuel and the average fuel-consumption in actual service. To solve this we must know what constitutes the upper limit of volatility and ascertain whether it is the end-point or something else. Prof. R. E. Wilson has brought out something of interest in this respect, but the question is not yet answered. The general problem of how to save fuel offers an unlimited field for discussion and research. Practically none of even the minor problems suggested in this connection has been solved definitely.

The highway problem has received less attention from the automotive industry, partly because its importance seems only to have been recently appreciated and it does not appear at first sight so immediate a problem of the industry. It has been heretofore mainly a matter of "good roads." So far as the passenger car alone is concerned, this may be a more or less correct viewpoint. Considering, however, the broad question of the economics of highway transportation, the problem is distinctly an automotive one. For instance, it is not possible to consider alone the design of a truck to give maximum ton-miles per dollar if it has a road on which to travel, without including also the cost of the highway. So long as registration fees for passenger cars paid for good roads, we were all reasonably content, but as soon as the highway is commercialized, so to speak, some one will be inquiring about the proper distribution of the highway bill among the different classes of traffic. Some answer to this question must be made. Perhaps it is a problem for the road engineer, but the automotive engineer will be very much interested in both the answer and the method of arriving at that answer. The nature of this answer, or the relative license fees that may be based on it, will be a large factor in deciding what sort of truck will be most economical for any given class of service.

General Effect of the Fuel Situation

Returning to the fuel problem, the first question that comes to mind is the general industrial one as to what the probable future of the situation is as regards fuel; that is, what is the relation that the probable supply, quality and price of fuel will have in the general development of the industry as regards design, usage and sales. It is not difficult to arrive at the general conclusion that fuels probably will be higher in price, and not change

very much in quality for some time. As a matter of fact, the automotive industry ought to promulgate a very strong plea for a uniform quality of fuel for some reasonable period of time.

The next questions are in regard to what effect increased fuel prices will have upon the situation in the automotive industry and what the automotive industry can do about it. These are big questions. There has been an enormous amount of discussion on the subject and it seems that the question has been in the main thoroughly covered and the lines of possible improvement thoroughly defined, but one feature of the problem in particular seems not to have been given the consideration it deserves. Perhaps this is because it is altogether too difficult. What is the cause of the apparently unnecessary actual wastage of unburned fuel?

One research appears to have yielded some data on this point. This is the experimental work of A. C. Fieldner and his associates in the Bureau of Mines. The paper by Fieldner, Straub and Jones on Automobile Exhaust Gases and Vehicular-Tunnel Ventilation showed conclusively that about 25 per cent of the gasoline that goes through the engine of the average motor vehicle is not burned but remains as combustible material in the exhaust; and there is plenty of general information that shows the same thing. This is essentially a question requiring statistical research; that is, it requires a knowledge not so much of what can be done in the laboratory, by the experimental engineer on the road, or with any particular kind of equipment under experimental conditions, but of what the average 9,000,000 users throughout the country will do with the average car under average driving conditions. What does the average user demand in the way of acceleration and what will he endure in the way of inconvenience? How must his carbureter be adjusted to satisfy him and how much can he be induced to learn about the saving of fuel? How can it be impressed upon him that fuel economy is necessary? If fuel wastage does not cost him very much, can he still be induced to improve conditions for the sake of society in general? There are many such questions that are out of the line of usual laboratory research, but they are properly research problems. It is true that they involve more or less psychological study, but we are coming to find that nearly everything in industry involves a large amount of this. Psychology is the heart of advertising and sales, and largely the heart of design. I believe we would not go far wrong if we knew a little more about the pyschology of the average driver, because it has a bearing on fuel consumption.

We do not know much about what mixture ratios are necessary to get good performance. F. C. Mock and P. S. Tice have given us some information on that subject. W. S. James, in his paper on the Elements of Automobile Fuel Economy gives some data as to the relation between the ability to accelerate and the average fuel-consumption, but this was only a beginning. These are simply suggested questions. Perhaps about all the Research Department will be able to do for some time is to suggest questions.

Another question that is of interest in this connection is one about which we know practically nothing, namely, What is the effect of what we term the end-point of the fuel on the average consumption throughout the country, and on crankcase dilution? To answer that question we first need to know what the real significance is of the quality that we have tried to define by the use of the term "end-point." We have the distillation curve; the last drop distils over at 437 deg. fahr. if the gasoline meets Government specifications. If it does not, the temperature may be 450 or 460 deg. fahr.; but, actually, that does not tell much about the true characteristics of the less volatile portions of the gasoline. We do not know whether it is the distillation temperature of the *last* fraction or that of the fraction distilling near the 85 or 90-per cent point that is important, in that it most affects the amount of crankcase dilution and the required temperature of the manifold. Prof. R. E. Wilson, of the Massachusetts Institute of Technology, presented at the 1921 Semi-Annual Meeting a more or less informal paper on Condensation Temperatures of Gasoline and Kerosene-Air Mixtures. This has, I believe, a decided bearing on this question. It suggests a rational method of determining the effective upper distillation-range of gasoline. This is a field that I think those who are interested in fuel per se should investigate. Such results should be rechecked in several independent laboratories.

As for the problems of the future, the future of the automotive industry depends on the adaptation of the future car to the future environment. Mr. Nelson's paper, already mentioned, gives some very interesting suggestions along that line. Mr. James' paper on the Elements of Automobile Fuel Economy attempts to give an analysis of some of the various factors that enter into the question of overall economy. However, there has not been much discussion of the underlying problem of what the general type or general trend of design of cars must be that will cause the public to buy in the largest quantities, or rather that will represent the largest total investment on the part of the public in automotive appliances. This is in reality the thing in which the industry as a whole is interested, marketing its product in such a way as to secure the maximum legitimate share of the expenditures of the Country for transportation. That can be done only by a proper relation between the design of the vehicle and the demand of the public. Much the same thing is true of at least a score of phases of the general problem of the relation between the cost and quality of fuel and the trend of design most favorable to success. We have a few partial answers to some of the questions, but few if any that are complete.

Fuel and Highway-Problem Bibliography

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The Relation of Motor-Vehicle Transportation to Highway Design

By H. G. Shirley[1]

Washington Section Paper

THE author emphasizes the need for exact data, and for highway design based thereon, relative to the type and character of construction that shall be used in building highways after the factors of safe wheel and axle loads and the bearing power of subgrades shall have been determined and agreed upon by motor-vehicle builders and highway engineers in concert. Adequate highways will not be possible before this has been accomplished. This idea is elaborated in the interest of effecting highway-construction standardization.

THE past design of highways has been rather uncertain, the selection of the type and thickness of the surfacing having been made by an empirical rule or determined by the judgment of the engineer in charge. Very often a type of surfacing has been used because it had given satisfactory service in some other locality. The engineer believed that the requirements would be no greater on the road under consideration, frequently without any study of the soils composing the subgrade and foundation. In many instances the subgrade and foundation have been of a character entirely different from that of the highway from which the conclusions were drawn.

The highways of the Country are being built without the use of definite mathematical calculations and designs based thereon. The type and character of construction represent the judgment of the engineer in charge, rather than a logical known design. Before the advent of the heavy motor vehicle the surfacing would loosen up in the spring and heave, when the subgrade had become saturated, but the traffic being light and the vehicle having iron tires the surface would be rolled back and reconsolidate as soon as the subgrade had dried out and settled. This would be repeated for a number of years before the surfacing would break up. But when a heavy motor vehicle strikes the surfacing over a saturated and yielding subgrade, it destroys it completely, and the effective service of the highway is greatly reduced and soon destroyed. Conditions have changed so rapidly that it is necessary now that some investigation and study be made of the subgrade so that it can be stabilized and its bearing power determined. This, together with knowledge of wheel and axle loads, will enable the highway engineer to design a slab or surfacing that will have the required strength to carry the specified load safely. Not until these two factors are known will we be able to solve the equation. In the meantime road designing will be erratic and like guess-work.

Highway Construction Standardization

Motor-vehicle builders and users have aimed much unfavorable criticism at the highway engineer because of failures of highways built 10 or 20 years ago. Motor-vehicle designers would not claim that the vehicles sold to the public 10 or 15 years ago are as usable and capable as the vehicles sold today. I can recall the time when motor-vehicle models were changed about every six months, and few remained unchanged longer than a year. Motor-vehicle design has become more stabilized but is changing constantly to meet conditions. The history of the highway is just the same; it occupies the same position relatively as the vehicle.

The motor-vehicle producer and owner would not acquiesce in a plan that would put an unlimited load on their vehicles. They would not adopt as a slogan, build the truck to carry the load, regardless of the limit of its capacity. But the highway engineer is told daily to build highways to carry unlimited loads. No body of men is more interested in controlling the load carried by the vehicle, and properly so, than the motor-vehicle builders and owners. I congratulate them on the position they have taken against overloading the vehicle, but they should not criticize the highway engineer for taking the same position with regard to the highway. It is just as important to carry the principle down to the road surfacing and the subgrade. It is my opinion that in the near future maximum wheel and axle loads will be specified for each class of surfacing. Highway engineers and motor-vehicle producers and owners must work out a logical and economic unit to be operated over the highways of the country, and determine the reasonable wheel and axle loads to be used. When this has been done and the research departments now engaged on the problem shall have determined the bearing power of the subgrade, the highway engineer can proceed to design a surfacing that will carry the specified load throughout the entire year without danger of it being destroyed.

This is the foundation on which we must build, and before such a foundation shall have been determined, the problem of highway design will not be solved and there will be a gross waste of public funds. Aside from the matter of highway bridges, highway engineers are not interested in gross loads. The gross load can be made exceedingly heavy, provided it is distributed over the proper number of axles and wheels. This can be accomplished by using trailers or employing additional axles and wheels under the truck, whichever is more economical, but a limited wheel load must be established and adhered to strictly if the highways of the Country are to be standardized and built so that they will perform the work they are supposed to do without being destroyed.

Subgrade Soils

The soils composing subgrades are very diversified and have numerous characteristics. This makes the problem very complicated. The soils must be classified. Their bearing power must be determined in such a manner that the information can be used by the engineer and the contractor on the work. The problem must be reduced to a practical and simple basis on which the highways of the Country can be built with an assurance of stability. The investigation of soils now being made by the Bureau of Public Roads, leading highway departments and universities, probably will result in some method of deter-

[1]Secretary, Federal Highway Council, Washington.

mining and improving their bearing power, possibly by chemical or mechanical treatment. If so, the unknown quantities will then become known and the engineers will be able to design highways and railroads just as exactly as motor trucks and highway bridges are designed today.

Political Influences

Political interference in highway building makes it difficult to construct a road as it should be constructed. Appropriations are usually made to cover the cost of a highway between two stated points. This may be so great a distance that only by using a very narrow and thin surfacing can the work be done within the appropriation and such a surface is inadequate to meet the traffic conditions of the near future. When the highway engineer is given instructions to build such a highway and to select a type and width that will make the appropriation cover the cost of a road over the entire distance, he must carry out the instructions even when he knows that a great mistake is being made. Such a highway will have only a short life and high maintenance charges and be altogether an economic mistake. These political condiitons are impossible of control and will remain so until public sentiment demands that the building of highways be placed in the hands of men specially qualified to do such work. The highway engineer must gain the confidence of the public in such a way that it will leave much to his own judgment and skill.

Necessary Cooperation and Its Advantages

The highways of the Country are being built just as well as the public demands, and sometimes better. The value of a highway to a community or a State compensates for the cost of its construction and maintenance, even if it render service for only a few years. It is necessary very often to build a road of an inferior type so that it can earn enough money to replace itself with a higher type. The amount saved in operation over an improved as compared with an unimproved highway is such that, if capitalized, a fairly well traveled highway can be resurfaced annually. A further value that cannot be estimated in terms of money lies in the enjoyment and comfort the highway provides its users, in the service it renders to all the people who have access to it and in the abatement of loneliness. Statistics show that the lives of more farmers' wives are wrecked by insanity caused by isolation and consequent loneliness than by any other cause. The accessibility afforded by an improved highway induces contentment and happiness and makes the isolated farm accessible.

The aggregate of the appropriations available and the great amount of money that will be appropriated from time to time make it essential that the design, construction and maintenance of highways be put on a known basis. It is very necessary that designers, producers and owners of motor vehicles cooperate with highway engineers and devise a plan that will provide for a definite wheel and axle load and a maximum speed. When this has been done, the public should be educated to depend upon highway engineers for a thorough study of the traffic and to design highways that will carry present and probable future traffic in the most economical way. The public should realize that such highways will have longer life, perform greater service and eventually be more economical in every way, although their first cost is greater. Unless designers of motor vehicles and highway engineers can agree upon what constitutes reasonable wheel and axle loads, we cannot expect very much improvement in highway work. I trust that they will cooperate to a greater degree soon and thresh this problem out and arrive at a definite conclusion. Then we can proceed with the construction of our highways and know that the money appropriated will be so expended as to render the greatest service.

EXHAUST GAS IN FUEL CHARGE

SINCE internal-combustion engines were first used to drive motor cars, designers have sought to increase the power output per unit of piston displacement and the reliability of the engine. Great progress has been made along these lines, but today it is necessary for the engine to be not only powerful and reliable, but also economical in its fuel consumption.

In the early days of the automobile, a favorite topic for discussion was the influence of the spent gases remaining in the clearance space at the end of the exhaust-stroke. This dilution of the fresh charge was considered to have a bad effect, as evidenced by the number of scavenging devices that were developed. Most of these devices have been discarded and now methods are being suggested for adding exhaust gas to the induction system, thus increasing the amount of inert gas in the cylinder. The engineers' attitude seems to have changed from open hostility to toleration and finally to admiration. The first change is easily explained. Increased power was desired and thorough scavenging made this possible by permitting the introduction of a larger charge.

In adding exhaust gas to the induction system, a higher thermal efficiency has been the goal. Some investigators have found that increasing the amount of inert gas in the charge tends to prevent the fuel knock and therefore enables a high compression-ratio to be employed. Since thermal efficiency depends upon the expansion-ratio, which in the conventional engine equals the compression-ratio, it should be higher with a higher compression-ratio. Full-throttle tests apparently show this to be the case and from these results it has been concluded that the addition of exhaust gas will be even more beneficial at part-throttle. It is assumed that under such conditions a decrease in power is of no consequence and that the heat of the exhaust may be of considerable aid in vaporizing the fuel. Since in service the automobile engine is operated at part-throttle most of the time, it is under this condition that economy of fuel consumption is most important.

Nearly all investigators have noted that under light loads the engine will not fire mixtures having as high a ratio of air to fuel as that which gives the best economy at higher loads. This is probably because the inert gas with a partially open throttle forms so large a proportion of the total charge. The compression-pressure also is, of course, too low; many experimenters have ascribed the poor efficiency to this cause. To prove that the proportion of the exhaust gas is the predominant influence, an engine partly throttled was operated with the leanest air-fuel ratio with which it would fire regularly. The engine was again operated with a sufficient amount of exhaust gas admitted with the charge to reduce the engine power to the same value as had been obtained in the first test by throttling. Although the pressures in the latter case were considerably higher than before, not nearly as high an air-fuel ratio could be fired.

It seems fair to conclude, therefore, that the dilution of the charge by the spent gases remaining in the clearance volume makes it impossible at low throttles to employ those air-fuel ratios that if they could be fired would yield the maximum efficiency. If the exhaust gas that is present during normal operation forms a barrier to the use of high-efficiency mixtures, surely the designer ought to avoid any devices for adding still more dead gas to the charge.—Bureau of Standards Bulletin.

ACTIVITIES OF THE SECTIONS

Sections Calendar

BUFFALO
(Secretary—George H. Pettit, 1569 Jefferson Street, Buffalo)
Jan. 17—Pneumatic Truck Tire Temperatures. —Professor Ellenwood

CLEVELAND
(Secretary—E. W. Weaver, 5103 Euclid Avenue, Cleveland)
Dec. 16—Aviation Meeting—Speaker, Glenn L. Martin

DAYTON
(Secretary—R. B. May, Dayton Engineering Laboratories, Dayton)
Jan. 17—Lubrication.—Dr. H. C. Dickinson

DETROIT
(Assistant Secretary—Mrs. B. Brede, 1361 Book Building, Detroit)
Dec. 5—Aviation Dinner to Admiral William F. Fullam
Dec. 16—Light-Weight Pistons

INDIANA
(Secretary—B. F. Kelly, Weidely Motors Co., Indianapolis)
Dec. 12—Aviation Meeting

METROPOLITAN
(Secretary—F. E. McKone, 347 Madison Avenue, New York City)
Dec. 15—Aviation Meeting — Speakers, Ralph Upson, C. M. Manly, C. F. Redden and S. H. Philbin

MID-WEST
(Secretary — Taliaferro Milton, 140 South Dearborn Street, Chicago)
Dec. 29—The Laws of Thermodynamics. — Prof. C. A. Norman
Feb. 3—The Constitution of Matter.—Prof. H. B. Lemon
March 31 — Various Commercial Fuels and their Relative Characteristics

MINNEAPOLIS
(Secretary—C. T. Stevens, 13 South Ninth Street, Minneapolis)
Dec. 7—A Safety High-Pressure Boiler for Use in Automobiles.—Charles B. Page
The Bissell Caterpillar Stump Puller —E. F. Norelius.
The Engineering Field — Dr. C. A. Prosser

NEW ENGLAND
(Secretary—H. E. Morton, B. F. Sturtevant Co., Hyde Park, Boston)
Dec. 16—Aviation Meeting at Boston—Speaker, Prof. E. P. Warner
Jan. 13—Visit to Stanley Plant in Newton

PENNSYLVANIA
(Secretary—T. F. Cullen, Chilton Co., Market and 49th Streets, Philadelphia
Dec. 22—Aviation Meeting — Speakers, Ralph Upson, W. B. Stout and Assistant Postmaster-General Shaughnessy

WASHINGTON
(Secretary — Benjamin R. Newcomb, Victor Bldg., Ninth and G Streets, City of Washington)

ST. LOUIS EXTENSION MEETING
Dec. 1—Trend of Aviation Development. — J. G. Vincent

THE Buffalo Section held its first fall meeting on Nov. 15 in the rooms of the Buffalo Engineering Society at the Iroquois Hotel. R. W. A. Brewer gave a paper on the design of inlet-manifolds and the fundamental bases governing their dimensions. He described the method of determining the rate of heat transfer and discussed the evils of poor distribution.

The Cleveland Section held its first meeting of the season in the rooms of the Cleveland Engineering Society at the Hotel Winton on Oct. 21, about 80 members being present. The dinner preceding the technical session was attended by several members of the Council of the Society, including President Beecroft, who outlined the plans of the Society for the coming year.

H. A. Schwartz presented a paper on malleable cast iron, touching upon its history, manufacture and physical properties. He described in particular some recent drilling-speed tests that he had conducted.

The paper on lubrication by Dr. H. C. Dickinson that was scheduled for the meeting of the Dayton Section on Dec. 6, will be presented on Jan. 17.

The Detroit Section on Dec. 5 gave an Aviation Dinner to Admiral William F. Fullam in conjunction with the local Aviation Society and Board of Commerce, at which Past-President C. F. Kettering was toastmaster. The regular meeting of the Section will be held on Dec. 16 at which the subject of Light-Weight Pistons will be discussed.

The various basic principles underlying the design of several types of carbureters were described at the Detroit Section meeting of Oct. 28. The speakers were D. W. Kriedler, S. E. Taylor, E. H. Shepard and F. R. Perry.

The Indiana Section will hold an Aviation Meeting on Dec. 12, at which a number of prominent officials from McCook Field are expected to be present.

C. T. Myers gave some startling figures at the Metropolitan Section meeting on Nov. 17 regarding the probable proportions of replacement costs attributable to insufficient chassis lubrication.

The first of the excellently planned series of sessions on the thermodynamic theories upon which all engine design is or should be based was held at the rooms of the Western Society of Engineers on Oct. 31. Prof. Daniel Roesch spoke on Power Fundamentals and gave a classroom explanation of the terms and units used. The educational program of the Mid-West Section should be appreciated thoroughly by those members who covered the subjects indicated in their younger days and have since forgotten a large part of them, and by those who have not had previously the opportunity of learning the ground-work so necessary for intelligent design. The second talk of this series was given by P. S. Tice on Nov. 25. His subject was the vaporization of fuels and other phenomena.

Prof. C. A. Norman will discuss on Dec. 29 the laws of thermodynamics.

Two technical papers and a talk on the economic situation were given before the Minneapolis Section on Nov. 2. A. H. Bates had as a subject the power absorption in tractors from the engine to the ground. Prof. A. F. Moyer discussed rotative balance. F. E. Kenaston spoke of the relation of the banker to the automotive industry.

On account of his removal to New York City, where he is now engaged as manager of the Research Department of the Society, the Washington Section was forced to accept Dr. Dickinson's resignation as its chairman. The activities of the Section will be directed by Vice-Chairman F. H. Pope as administrative head during the rest of the season. Benjamin R. Newcomb has been elected secretary of the Section to succeed Archibald Black, who moved his office to New York City. At the meeting held on Nov. 4 M. E. Cheney spoke on recent spark-plug developments, explaining the theories upon which the design of spark-plugs for different conditions of operation is based. H. S. McDewell gave an account of his experience with the Ricardo supercharging engine, showing slides by way of illustration.

Many of the Sections have arranged to hold meetings on

various phases of aviation. The dates of these, so far as they have been decided upon at this writing, are given in the Sections Calendar. An article on what it is hoped to accomplish at these meetings appears elsewhere in this issue of THE JOURNAL.

At a meeting of the Pennsylvania Section held on Nov. 22, two very interesting papers were presented. The latest developments in the fuel situation were discussed by Thomas Midgley, Jr., and T. Orchard Lisle, editor of *Motorship*, New York City, spoke very entertainingly on modern Diesel engines and motorships. The latter paper was supplemented by numerous lantern slides showing typical applications.

NATIONAL MEETINGS OF THE SOCIETY

A RECENT issue of the Meetings Bulletin described in considerable detail the programs arranged for the several national meetings of the Society which will be held this winter. For this reason it is unnecessary to record anything but a brief outline of the plans in this issue of THE JOURNAL. The descriptions of the meetings are given in sequence.

THE CHICAGO FUEL MEETING.

In response to an invitation from the American Petroleum Institute, the Society has arranged to conduct two technical sessions on the matter of fuel uniformity during the convention of this organization of petroleum refiners at Chicago, Dec. 6 and 7. The meetings will be held in the Congress Hotel and will start promptly at 10 o'clock.

The program follows:

TUESDAY, DEC. 6

Quantitative Survey of the Petroleum Industry from the Standpoint of Production of Internal-Combustion Engine Fuel—Van H. Manning

Quantitative Survey of Automotive Engine Fuel Requirements — E. S. Jordan, of National Automobile Chamber of Commerce

Requirements of Motor Vehicle Fuel—H. M. Crane

Qualitative Limitation in Refining and Marketing—F. A. Howard

Volatility of Motor Fuel as Marketed in the United States—N. A. C. Smith

What Constitutes True Volatility?—Robert E. Wilson

Present Variations in Quality of Internal-Combustion Engine Fuel, Its Extent and Causes—C. K. Francis

WEDNESDAY, DEC. 7

Research Discussion

Limitations Imposed on Economy by Volatility Changes—F. C. Mock

Practical Effects of Too Low Volatility—O. C. Berry

THE ANNUAL MEETING.

The Annual Meeting of the Society will be held in New York City, Jan. 10-13, 1922. During this four-day period there will be eight technical sessions, the annual meeting of the Standards Committee, the business meeting of the Society and election of officers, the Dinner at the Hotel Astor and the Dance Carnival at the Hotel Pennsylvania. Harry Ricardo, the eminent British automotive engineer, will present a paper at the technical session on Thursday, Jan. 12, in which he will assemble the results of his extensive automotive research work for discussion by our members.

The schedule of events for the Annual Meeting follows:

TUESDAY, JAN. 10.

Morning—Standards Committee Meeting
Afternoon—Standards Committee Meeting
Evening—Aeronautic Session

WEDNESDAY, JAN. 11.

Morning—Annual Business Meeting
Election of Officers
Afternoon—Body Engineering Session
Motor Truck Transportation Session
Lubrication Session
Evening—Dance Carnival, Hotel Pennsylvania

THURSDAY, JAN. 12.

Morning—Research Session, Mr. Ricardo
Afternoon—Fuel and Engine Session
Automotive Materials Session
Evening—Annual Dinner, Hotel Astor

FRIDAY, JAN. 13.

Morning—Passenger Car Session

Preprints of the papers to be read at the Annual Meeting will be mailed only to those members requesting them. An application blank for ordering preprints was mailed to the entire membership with the last issue of the Meetings Bulletin.

THE CHICAGO MEETING.

The annual Chicago Meeting of the Society will be held in that city, Feb. 1, 1922. There will be two technical sessions, one in the morning and the other in the afternoon. Both of these technical meetings will be conducted at the Chicago Automobile Club and will be devoted principally to matters concerning operation and maintenance. The Chicago Dinner has been arranged at the Hotel Drake on the evening of the same day at 6.30 o'clock.

THE TRACTOR MEETING.

The Annual Tractor Meeting of the Society, which is held each year in conjunction with the National Tractor Show, will be convened in Minneapolis, Feb. 8 and 9. There will be two technical sessions devoted to tractor subjects, these being held during the afternoons of the two days noted. On Thursday evening, Feb. 9, the Annual Farm Power Dinner will be served. The location of the meetings and the dinner has not been determined at this date, but will be included in future meeting announcements. The Minneapolis Section will assist in the conduct of this Tractor Meeting and with their cooperation it is expected that an attractive technical program will be arranged.

OBITUARIES

JAMES CHASE RAPPLEYEA, service director for the Bethlehem Motor Corporation, Allentown, Pa., died Oct. 24, 1921, aged 43 years. He was born Dec. 19, 1877, at Rochester, N. Y., and was educated in the public schools there. He was owner of an automobile repair business in New York City from 1903 to 1906 and then, until 1911, was superintendent of automobile repairs for the O. J. Gude Co. in New York City. Becoming shop foreman for the Chalmers Motor Co. in 1911, he continued this work until 1916 and then was foreman and assistant to the service manager, progressively, for the Willys Overland Co., in New York City. Mr. Rappleyea became service director for the Bethlehem Motor Corporation in 1920. He was elected to Associate member grade in the Society March 25, 1918.

WILLIAM J. WALSH, assistant sales manager for the Buda Co., Harvey, Ill., died, Aug. 31, 1921, aged 51 years. He was born, Feb. 3, 1870, at Chicago. Following his common school education he received training along commercial lines and entered the employ of the Buda Co. about 1910. There he gained considerable experience in shopwork and later became identified with the sales department. He was elected to Associate member grade in the Society, June 21, 1917.

Applicants *for* Membership

The applications for membership received between Oct. 21 and Nov. 23, 1921, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ACKERMAN, PAUL CEDRIC, student, University of Michigan, *Ann Arbor, Mich.*

ALTHOUSE, ANDREW D., instructor, Cass Technical High School, *Detroit.*

BAMFORD, GEORGE F., instructor in ignition, starting and lighting, Motor Transport Training School, *Camp Holabird, Md.*

BAUMAN, JOHN NEVIN, student, University of Michigan, *Ann Arbor, Mich.*

BAYCROFT, LOUIS B., manager Boston service depot, Electric Storage Battery Co., *Philadelphia.*

BENTON, EDWARD L., service manager, Benton Electric Co., *LaCrosse, Wis.*

BLACK, GEORGE ANGLIS, JR., student, University of Michigan, *Ann Arbor, Mich.*

BOCK, OSCAR LOUIS, student, Iowa State College, *Ames, Iowa.*

BOYD, GEORGE W., proprietor, Boyd's Garage, 129 Brock Street, *Kingston, Ont., Canada.*

BURGER, GEORGE EDWIN, JR., student, Rensselaer Polytechnic Institute, *Troy, N. Y.*

BORRESON, HARRY, foreman, practical test laboratory, American Bosch Magneto Corporation, *Springfield, Mass.*

BRENNER, CLYDE A., treasurer and general manager, Brenner Automobile Supply Co., *St. Louis.*

CARLSON, AMEL R., vice-president and general manager, Commonwealth Motors Co., *Chicago.*

CARLSON, R. E., chief of tank section, tank, tractor and trailer division, Ordnance Department, *City of Washington.*

CARTER, THOMAS FREDERICK, JR., student, Georgia School of Technology, *Atlanta, Ga.*

CLINE, EARL E., chief engineer and superintendent, Ernest Holmes Co., *Chattanooga, Tenn.*

DEMPSEY, WILLIAM L., consulting engineer and president, Dempsey Cycle Co., *Philadelphia, Pa.*

DIEDERICHS, H., director of school of mechanical engineering, Cornell University, *Ithaca, N. Y.*

DRAPER, HOWARD W., supervisor of automotive courses, Franklin Union, 41 Berkeley Street, *Boston.*

DURLAND, HARRY S., instructor, Pratt Institute, *Brooklyn, N. Y.*, and salesman, Double Seal Ring Co., 1834 Broadway, *New York City.*

EASTMAN, EDWARD HUNT, student, Iowa State College, *Ames, Iowa.*

FITZPATRICK, JAMES R., secretary, Haskelite Mfg. Corporation, 133 West Washington Street, *Chicago.*

FLORO, MARTINIANO, student, University of Illinois, *Urbana, Ill.*

FRANCIS, C. K., chief chemist and technical superintendent, Cosden & Co., *Tulsa, Okla.*

GAA, VICTOR H., model maker, Edmund & Jones Corporation, *Detroit.*

GAGER, JOHN B., service manager, American Motor Truck Co., *Newark, Ohio.*

GANSTER, LOUIS T., president and general manager, Berks Auto-Ignition Co., 514 Cherry Street, *Reading, Pa.*

GELPKE, ADOLF, chief draftsman, Autocar Co., *Ardmore, Pa.*

GOOD, CHARLES WINFRED, instructor, University of Michigan, *Ann Arbor, Mich.*

GUTEKUNST, HERMAN, assistant chief engineer and assistant general manager, Ray Battery Co., *Ypsilanti, Mich.*

HALLADAY, MERTON EMERSON, student, Rensselaer Polytechnic Institute, *Troy, N. Y.*

HAMILTON, ERWIN, instructor, New York University, University Heights, *New York City.*

HARRY, GORDON W., student, University of Michigan, *Ann Arbor, Mich.*

HART, RICHARD LECKLIDER, student, University of Michigan, *Ann Arbor, Mich.*

HEDRICH, O. H., JR., student, University of Illinois, *Urbana, Ill.*

HOPKINS, FRED J., student, Georgia School of Technology, *Atlanta, Ga.*

HOUSER, JESSE E., chief inspector, Delco-Light Co., *Dayton, Ohio.*

HOWELL, K. J., 802 Ocean Avenue, *New London, Conn.*

LATHEM, JOSEPH GAULT, JR., student, Georgia School of Technology, *Atlanta, Ga.*

LINDSTROM, CARL T., student, Rensselaer Polytechnic Institute, *Troy, N. Y.*

LITTLEFIELD, L. H., engineer, Barnsdall Refining Co., *Kansas City, Mo.*

LOVEJOY, RALPH M., president, Lovejoy Mfg. Co., *Boston.*

MCMAHON, ROBERT A., manager, Boyd's Garage, 129 Brock Street, *Kingston, Ont., Canada.*

MALONE, D. G., student, University of Illinois, *Urbana, Ill.*

MURPHEY, JOHN EDMUND, 2ND, student, Georgia School of Technology, *Atlanta, Ga.*

NEUHART, J. H., general manager, Liggett Spring & Axle Co., *Monongahela, Pa.*

POWER, E., superintendent of equipment, Union Oil Co., *Los Angeles, Cal.*

RICH, RALPH E., president and chief engineer, Amalgamated Metals Co., *Chicago.*

RIPLEY, JOSEPH P., general manager, Brewster & Co., Bridge Plaza, *Long Island City, N. Y.*

ROEMER, ARTHUR, designer, Hupp Motor Car Corporation, Mount Elliott & Milwaukee Avenues, *Detroit.*

ROOKS, ALFRED WENDELL, student, School of Engineering, *Milwaukee.*

ROSECRANS, CRANDALL Z., research assistant in mechanical engineering, University of Illinois, *Urbana, Ill.*

ROWELL, HENRY SNOWDEN, director of research, Research Association of British Motor & Allied Manufacturers, *London, England.*

RUGE, EDGAR P., road service man, Dorris Motor Car Co., *St. Louis.*

SACKETT, A. H., service manager, Elgin Motor Car Corporation, 54 East 51st Street, *Chicago.*

SCHROYER, E. C., instructor in automotive engineering, Georgia School of Technology, *Atlanta, Ga.*

SCHWARTZ, CHRISTIAN, testing engineer, Studebaker Corporation of America, *Detroit.*

SEMINO, ANGELO F., student, Leland Stanford Junior University, *Stanford University, Cal.*

SHARON PRESSED STEEL CO., *Sharon, Pa.*

SHRIVER, LIEUT. E. F., in charge of motor transport unit, Georgia School of Technology, *Atlanta, Ga.*

SODERHOLM, CAPT. WALTER H., Ordnance Department, *Rock Island Arsenal, Ill.*

SPRIGGS, CECIL T., student, Rensselaer Polytechnic Institute, *Troy, N. Y.*

STALNAKER, R. H., assistant highway engineer, California Highway Commission, Forum Building, *Sacramento, Cal.*

STROEBEL, GEORGE ARTHUR, student, Rensselaer Polytechnic Institute, *Troy, N. Y.*

STROHL, GEORGE RALPH, mechanical engineer, Autocar Co., *Ardmore, Pa.*

STURTEVANT, FOSTER E., draftsman, Ward Motor Vehicle Co., *Mount Vernon, N. Y.*

SVENSON, CHARLES W., mechanical superintendent, Corbin Screw Corporation, *New Britain, Conn.*

TERHUNE, JOHN E., superintendent, Cox Brass Mfg. Co., *Albany, N. Y.*

TETHER, CLIFFORD F., student, Rensselaer Polytechnic Institute, *Troy, N. Y.*

TIFFANY, HALSTED R., student, Rensselaer Polytechnic Institute, *Troy, N. Y.*

TITCHENER, WALTER E., production manager and engineer, Cortland forging division, of Brewer-Titchener, *Cortland, N. Y.*

TRAMMELL, LEANDER NEWTON, student, Georgia School of Technology, *Atlanta, Ga.*

ULRICH, THEODORE, layout draftsman, Hupp Motor Car Corporation, *Detroit.*

VIETS, ELTON WILLARD, student, University of Michigan, *Ann Arbor, Mich.*

WHITTLESEY, F. E., manager, Raymond Mfg. Co., Ltd., *Corry, Pa.*

WILLIAMSON, JOHN EARL, student, Rensselaer Polytechnic Institute, *Troy, N. Y.*

WRIGHT, WARREN O., assistant chief engineer, Bowen Products Corporation, *Auburn, N. Y.*

ZEDER, JAMES C., student, University of Michigan, *Ann Arbor, Mich.*

Applicants *Qualified*

The following applicants have qualified for admission to the Society between Oct. 10 and Nov. 10, 1921. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

ALLISON, FIRST-LIEUT. PHILIP W. (S M) Eighth Field Artillery, Schofield Barracks, *Hawaii.*

ANDERSON, A. E. (A) garage foreman, Standard Oil Co., *Spokane, Wash.,* (mail) 211 South Ralph Street.

ANDERSON, F. W. (M) vice-president and general manager, Northwestern Motor Co., *Eau Claire, Wis.*

BARTLETT, PERCY H. (A) machine shop superintendent, Sinclair Refining Co., Chicago, (mail) 108 South Scoville Avenue, *Oak Park, Ill.*

BERLIET, MARIUS (F M) general manager, Societe des Automobiles M. Berliet, *Lyons, France.*

CHAMBERS, F. W. (E S) 45 Cecil Street, *Toronto, Ont., Canada.*

DAMES, GUST A. (A) mechanical engineer, 255 West 52nd Street, *New York City.*

DANVILLE MALLEABLE IRON CO. (Aff) *Danville, Ill.*
Representative: Smith, William C., assistant general manager.

DENNIS, HENRY A. (A) supervisor of motor equipment, Texas Co., 201 Devonshire Street, *Boston.*

DEWAIDE, HAL (J) sole owner and designer, Hal DeWaide "Sport Car," 434 West Salmon Street, *Portland, Ore.*

DOTEN, EVERETT F. (J) engineering department, Muskegon Motor Specialties Co., *Muskegon, Mich.*

EVANS, CLARK (E S) student, University of Michigan, *Ann Arbor, Mich.,* (mail) 1218 Washtenaw Avenue.

FISH, MELVIN L. (J) automotive designer, Fox Motor Car Co., *Philadelphia,* (mail) 5718 North Sixth Street.

FLAGE, JOHN E. (A) superintendent of manufacturing, Ray Battery Co., *Ypsilanti, Mich.,* (mail) 608 Pearl Street.

FOSTER, ERNEST H. (M) mechanical engineer, *Dongan Hills, Staten Island, N. Y.*

HANOVER, H. T. (A) president and general manager, Apex Motor Co., *Ypsilanti, Mich.*

HERRICK, EDWARD D. (M) assistant chief engineer, Lycoming Motors Corporation, *Williamsport, Pa.*

HOLMES, F. E. (A) head machinist, Walter M. Murphy Motors Co., *Pasadena, Cal.,* (mail) 202 West Walnut Street.

KERSHOW, W. V. (A) Overland Syracuse Co., Syracuse, N. Y., (mail) 324 Greenwood Place.

KUBACKA, JOSEPH E. (J) body engineer, Victor Page Motors Corporation, *New York City,* (mail) 1073 First Avenue.

LINDSAY, H. O. (A) chief engineer, department of internal-combustion engines, Pure Oil Co., *Minneapolis,* (mail) 1302 First Street, South.

LOUPRET, LIONEL N. (M) electrical engineer, Kokomo Electric Co., *Kokomo, Ind.,* (mail) 14 West Elm Street.

MACNAB, F. B. (A) business manager, General Motors Research Corporation, *Dayton, Ohio.*

MCKINLEY, WILLIAM A. (M) chief engineer, Detroit Pressed Steel Co., 6660 Mount Elliot Avenue, *Detroit.*

MEESON, WILLIAM P. (F M) works manager, Arrol-Johnston, Ltd., Dumfries, (mail) Westbourne House, *Maxwelltown, Scotland.*

MITCHELL, G. I. (M) assistant professor of mechanical engineering, University of Wisconsin, *Madison, Wis.,* (mail) 97 South Warren Street.

MORAN, CHARLES B. (J) chief engineer, American Die & Tool Co., Second and Buttonwood Streets, *Reading, Pa.*

MONTANYE, JAMES (A) service manager, General Motors, Ltd., 1 Thurloe Place, *London, S. W. 7, England.*

REID, ALBERT R. (M) chief chemist, U. S. Light & Heat Corporation, *Niagara Falls, N. Y.,* (mail) 354 First Street.

ROGERS, JAMES B. (A) experimental engineer, Joy Ball Bearing Co., *Chicago,* (mail) 457 North Racine Avenue.

RUNYAN, WILLIAM B. (A) vice-president and general superintendent, Dayton Malleable Iron Co., *Dayton, Ohio,* (mail) P. O. Box 980.

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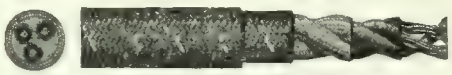

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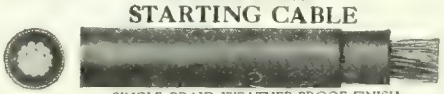

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Personal Notes of the Members

Items regarding changes in business connections, promotions, etc., are desired from the membership for insertion in these columns. This will enable members to keep their friends informed of their whereabouts and will also assist in keeping the records of the Society up to date.

Prof. C. A. Adams, until recently chairman of the engineering division of the National Research Council, New York City, has resumed his duties as Lawrence professor of electrical engineering at Harvard University, Cambridge, Mass.

F. G. Alborn, formerly chassis engineer for Hare's Motors, Inc., Bridgeport, Conn., has been made chief engineer for the American Motor Truck Co., Newark, Ohio.

C. S. Ash has opened an office for the practice of automotive engineering at 5718 Russell Street, Detroit. He was previously vice-president of the Detroit Wheel Corporation, Detroit.

Floyd E. Badger, who for the past 10 months has been a member of the sales-engineering staff of the Detroit Steel Products Co., Detroit, has been appointed sales manager of the chassis spring division of that organization. From 1910 to 1918 he was manager of the spring plant of the Standard Parts Co., at Flint, Mich., and during the war he was in charge of production at Motor Transport Corps base repair shops at Camp Holabird, Md. Following his discharge from Government service Mr. Badger returned to the Standard Parts Co. as manager of its Perfection Spring plant at Cleveland.

William R. Beckman has been elected vice-president in charge of engineering of the recently organized Richelieu Motor Car Corporation, Asbury Park, N. J. He was for many years assistant to Fred S. Duesenberg and prior to that was chief engineer of the Loew-Victor Engine Co., Chicago.

E. A. Blake has severed his connection with the Transport Truck Co., Mount Pleasant, Mich., where he was in charge of the experimental department. He has not announced his plans for the future.

Lloyd J. Bohan is now connected with the Chicago office of the Wisconsin Parts Co., Oshkosh, Wis., having severed his connection with the Union Motor Truck Co., Chicago.

Alfred C. Boock is no longer layout draftsman for the Waterloo Gasoline Engine Co., Waterloo, Iowa, but holds a position as designer with the St. Cloud Truck Co., St. Cloud, Minn.

Raymond F. Buckley, who has for the last year been doing patent and consulting engineering work, has become associated in a similar capacity with Robert H. Hassler, Inc., Indianapolis, Ind.

C. W. Butterfield is no longer sales manager for the Herschell-Spillman Motor Co., North Tonawanda, N. Y., but now holds a similar position with the Apex Motor Corporation, Ypsilanti, Mich.

Everett J. Cook, who was formerly chief engineer of the Oklahoma Auto Mfg. Co., Okay, Okla., has organized the

(*Continued on page* 4)

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PERSONAL NOTES OF THE MEMBERS

Continued

firm of Everett J. Cook & Co. The company, which has its offices in the Nicholas Building, Toledo, is offering its services as engineers, purchasing agents and traffic managers to industrial establishments.

M. H. Cook has resigned as machine designer in the engineering experiment station at the University of Illinois, Urbana, Ill., and has accepted a position as chief draftsman with the Beneke & Kropf Mfg. Co., Chicago.

Charles S. Crawford has been appointed consulting engineer for the Cole Motor Car Co., Indianapolis. He was formerly vice-president in charge of engineering for the Premier Motor Corporation, also of Indianapolis.

C. W. Curtiss, formerly general manager of the Splitdorf Electrical Co., Newark, N. J., and later president and general manager of the Van Sicklen Speedometer Co., also of Newark, until its sale to the Stewart-Warner Speedometer Corporation, has been elected president of the Tiffany Mfg. Co., 50 Spring Street, Newark.

S. F. Delvin is no longer connected with the Government division of the Holt Mfg. Co., Stockton, Cal., as chief draftsman. He has not announced his plans for the future.

James E. Diamond, formerly sales manager and a member of the firm of Walker M. Levett Co., New York City, has become general manager of the National Piston Co., 347 Madison Avenue, New York City.

Clyde E. Dickey has been appointed sales representative for the Metropolitan district for the Peerless Drawn Steel Co., Massillon, Ohio, with headquarters at New York City.

James Dykstra has severed his connection with the Oakland Motor Car Co., Pontiac, Mich., and is now affiliated with the Dare Aircraft Co., Detroit.

A. J. Fitzgibbons is no longer traveling salesman for the Merchant & Evans Co, Philadelphia. but has been elected chairman of the board of directors of the McDermott Steel Corporation, Buffalo, N. Y.

R. P. Flower has been elected vice-president of the Federal Automotive Sales Co., Chicago.

Herbert J. Graham has been made sales engineer for the Electric Service Supplies Co., Philadelphia.

T. G. Graham, formerly factory manager for the Inland Rubber Co., Chicago, is now connected with the Mason Tire & Rubber Co., Kent, Ohio.

George A. Hack, until recently assistant metallurgist with the Champion Ignition Co., Flint, Mich., is now associated with Don W. Coy, consulting engineer, 1227 East 75th Street, Chicago.

A. W. S. Herrington has been appointed engineer of the Motor Transport Division of the office of the Quartermaster General of the Army, City of Washington, succeeding W. T. Norton, Jr., who resigned last February. Mr. Herrington was formerly assistant chief engineer of the Harley-Davidson Motor Co., Milwaukee.

Bradford B. Holmes has opened an office as industrial engineer at 95 Liberty Street, New York City. He was formerly chief engineer for Miller Reese Hutchison, Inc., New York City.

Floyd B. Hubbard, chief engineer and production manager of the tractor department of the Parrett Tractor Co., Chicago Heights, Ill., has severed his connection with that company. His future plans have not been announced.

(*Continued on page* 6)

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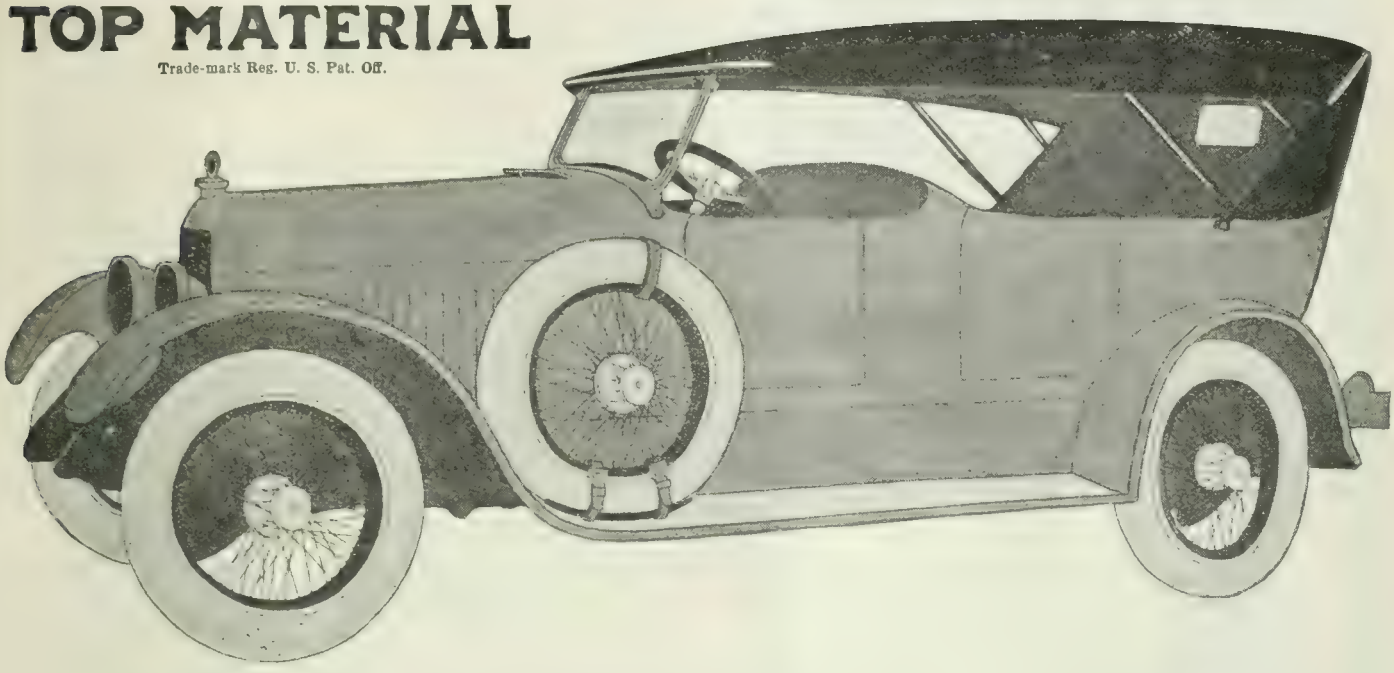

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Branch Sales Offices and Stock Rooms

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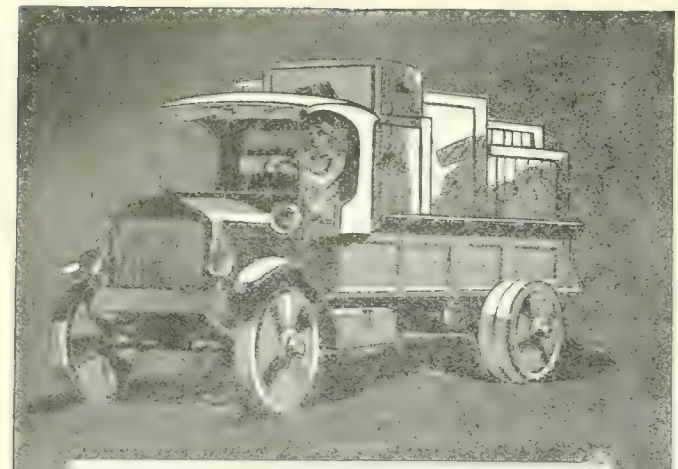


For All Insulation

Vul-Cot Fibre

Machines as readily as lead

VUL-COT Fibre comes in sheets, rods and tubes. It's dense and tough and has an extremely low friction co-efficient. This gives it the greatest wear resistance of any insulator.

VUL-COT Fibre is always uniform — never contains fissures, hard or soft spots, grit or other foreign matter. Edge tools used in machining it are subjected to little wear. Here are the physical properties of *VUL-COT* Fibre:

Tensile strength 9,000 to 14,000 pounds per square inch—compressive strength 32,000 to 67,000 pounds per square inch —resistance to shearing 9,000 to 13,000 pounds per square inch—specific gravity 1.2 to 1.5. Electrical rupture 100 to 400 volts per mil.

—And these are the properties that have made *VUL-COT* Fibre "The Material with a Million Uses." We have a book bearing this title. We'll send it: Tell us where. Also consult the *VUL-COT* Service Dept. in your individual problems.

BY INVITATION MEMBER OF

AMERICAN VULCANIZED FIBRE CO.
521 Equitable Bldg., Wilmington, Del.

SALES OFFICES
BOSTON PHILADELPHIA CLEVELAND CHICAGO
NEW YORK PITTSBURGH DETROIT ST. LOUIS
Complete Stock for Immediate Shipment at Chicago

Western Agents
Western Electric Company
SAN FRANCISCO SEATTLE LOS ANGELES
PORTLAND ATLANTA

Canadian Agents
Northern Electric Company
Limited
MONTREAL TORONTO WINNIPEG
OTTAWA HALIFAX ALBANY
REGINA VANCOUVER

Make it of VUL-COT Fibre

Personal Notes of the Members

Continued

Herbert S. Jandus has accepted a position as engineer for the C. G. Spring Co., Kalamazoo, Mich.

Roy F. Johnson, until recently sales engineer for the Iron Mountain Co., Chicago, has become affiliated with the Atlantic Die-Casting & Mfg. Co., also of Chicago, in a similar capacity.

George W. Kerr has severed his connection with the H. & M. Body Corporation, Racine, Wis. He has not announced his plans for the future.

Robert A. Klossner has accepted a position as machinist for the MacDonald Steam Automobile Corporation, Garfield, Ohio.

G. J. Lang, formerly assistant to the president of the American Bosch Magneto Corporation, Springfield, Mass., has become affiliated with Gray & Davis, Inc., Boston.

William F. Legg is doing development work on a portable saw outfit for sawing trees and logs for the Chain Saw Co., New York City.

Otto L. Lewis has joined the tool design department at the tractor works of the International Harvester Co., Chicago, as engineer.

Henry G. McComb has accepted a position as sales engineer for the American-La France Fire Engine Co., 250 West 54th Street, New York City.

G. C. McMullen has been transferred from San Francisco, where he was acting as sales engineer for the Timken Roller Bearing Co., to Canton, Ohio, where he will be manager of the industrial bearings division of that company.

Joseph A. Mackle has become re-associated with the Daimler Co. in the capacity of director and manager of Stratton-Instone, Ltd., which has taken over the Daimler branch in London. In 1908 he entered the service of the Daimler organization, leaving in 1914 to become director and general manager of the Willys-Overland, Ltd., London.

Carl T. Mason has accepted a position as chief engineer for the Tiffany Mfg. Co., Newark, N. J. He formerly held a similar position with the Splitdorf Electrical Co., also of Newark.

C. G. Mills is now associated with the Alemite Shop, Wichita, Kan.

Clinton E. Morgan, assistant general manager of the Brooklyn City Railroad Co., Brooklyn, N. Y., was elected general manager at a recent meeting of the board of directors. In his new post Mr. Morgan will be in control of the operation of all the street railway lines operating in the boroughs of Brooklyn and Queens, New York City.

J. S. Murphy has been elected vice-president of the Kelly Valve Co., Chicago. He was formerly associated with the Society of Industrial Engineers, also of Chicago.

Emanuel Nides is no longer chief engineer for the Standard Steel & Bearings, Inc., Philadelphia. His plans for the future have not been announced.

C. A. Obermaier has severed his connection with the Southern Motors Mfg. Association, Ltd., Houston, Tex., as chief engineer and production manager, and has taken over the exclusive sales rights for the State of California for uradia, and is doing business under the name of the California Uradia Sales Co., Los Angeles.

M. Olbeter has accepted a position as designer for the Lawrance Aero-Engine Corporation, 644 West 44th Street, New York City.

Victor C. Parker is no longer manager for the Waterloo Buick Co., Waterloo, Iowa. His plans for the future have not been announced.

(*Continued on page* 8)

THE STEEL PRODUCTS CO.

ENGINEERING SERVICE **MANUFACTURING SERVICE**

This is a complete service—not **engineering alone** or **manufacturing only**, but the combination which makes for intelligent fulfillment of the requirements necessary to provide the following parts in a manner to satisfy the needs of the individual assemblies:

AT MAIN PLANT—Cleveland, Ohio

Tappets **Valves** **Bolts**

Piston Pins **ALL KINDS** **KING SPRING CONNECTING ROD TIE ROD**

AT MICHIGAN PLANT—7731 Conant Road, Detroit

Starting Cranks **Drag Links**
Rod Assemblies
Torque Rods—Torque Hangers

AT BOLT AND SCREW PLANT—Cleveland, Ohio

Chassis Bolts—Plain Bolts All Kinds

Cap Screws—Coupling Bolts

The same idea prevails at all plants: "To be a Department of Your Plant" and all effort is made to meet your conditions satisfactorily.

The Deppé Motors Corporation

during the last two years has developed and thoroughly tested out in final commercial form its

SUPERHEATED GAS SYSTEM

(Patented)

for the six-cylinder 3¼ x 5

HERSCHELL SPILLMAN MOTOR

MOTOR VEHICLE MAKERS

Utilizing this combined product in cars of 3000 lb. class, may advertise and prove by use in the hands of the public the following valuable sales points:

WITH 100 lb. COMPRESSION
FIXED SUPERHEATED GAS MIXTURE
FIXED ADJUSTMENTS IN ALL PARTS
WITH CONTROLLED COMBUSTION.

Develop maximum speeds 60 m. p. h.

22 miles per gallon with existing or any future motor fuels

1600 miles per gallon of lubricant

10 to 30 m.p.h. in 9 seconds

Radiator water normally around 130° F.

NO THERMOSTATS

Easy starting, no loading

Practically eliminates carbonization

No preignition, no autoignition

No so-called detonations

Eliminates vibration due to fuel conditions

Practically eliminates lubricating oil dilution

No overheating of metals

Practically eliminates valve grinding

Practically eliminates bearing adjustments

Practically eliminates spark-plug troubles

PRACTICALLY ELIMINATES GEAR-SHIFTING.

Full information and demonstrations for Works Engineers by appointment only.
C. E. Parsons, Chief Engineer

Deppé Motors Corporation
151 Church Street, New York

PERSONAL NOTES OF THE MEMBERS

Concluded

F. H. Patten has severed his connection with Johns-Manville, Inc., for whom he was special representative at St. Louis. His plans for the future have not been announced.

R. A. Picard has been appointed general sales manager of the Metal Stamping Co., Long Island City, N. Y. He was formerly vice-president of A. J. Picard & Co., Inc., New York City.

William J. Quinn, formerly superintendent of service of the Murray-Van Sicklen Co., Chicago, has become associated with the J. W. Murray Mfg. Co., Detroit.

M. H. Roberts, chief engineer of the Franklin Railway Supply Co., New York City, has been appointed by Director H. Foster Bain of the Bureau of Mines, chairman of a board of engineers to study the production of helium in Texas.

N. G. Rost, who was formerly sales manager of the Duesenberg Motors Corporation, has been elected president of the newly formed Richelieu Motor Car Corporation, Asbury Park, N. J.

Ira S. Snead, general sales manager of Snead & Co., Jersey City, N. J., has been elected vice-president of the company, succeeding the late H. P. Macdonald.

Joseph T. Snow has been made sales engineer of the Beacon Oil Co., Boston. He was formerly chief engineer of the Texas Co., also of Boston.

C. M. Tichenor, formerly assistant general manager of the Pierce-Arrow Motor Car Co., Buffalo, N. Y., has become associated with the Rickenbacker Motor Co., Detroit.

F. W. Trabold has severed his connection with J. H. Williams & Co., Brooklyn, N. Y., where he held the offices of second vice-president and general sales manager. His plans for the future have not been announced.

James J. Tracy has been elected president of the Avenue Motor Co., Cleveland. He was formerly vice-president of the J. T. Tractor Co., also of Cleveland.

Wallace W. Tuttle, until recently vice-president and general manager of the Engineering Service Corporation, Detroit, has become associated with the Four Wheel Hydraulic Brake Corporation, Detroit.

John A. Vanneman has joined the Remy Electric Division of the General Motors Corporation, Anderson, Ind., as service engineer. He was previously engineer for Eisemann Magneto Corporation, Brooklyn, N. Y.

A. L. Vargha has accepted a position as designer with the Harrison Radiator Co., Lockport, N. Y. He formerly was connected with the Pittsburgh Model Engine Co., Pittsburgh, in the same capacity.

W. J. Walker, formerly engineer for the Menominee Truck Co., of Wisconsin, Clintonville, Wis., is now chief engineer for the Fulton-Flyer Truck Co., Houston, Tex., and is laying out the ¾-ton truck to be assembled by this company.

Harry F. White has severed his connections with the General Motors Export Co., New York City. No announcement has as yet been made on his plans for the future.

Louis B. Williams, formerly advertising manager for the Electric Auto-Lite Corporation, Toledo, has been made vice-president of the Osborn Sales Corporation, Kansas City, Mo.

Ernest J. Wissel has been made service director of the Fuller Automobile Co., Cincinnati. He was formerly connected with the Highland Auto Garage Co., Fort Thomas, Ky.

M. L. Yuster has been elected president of the Packard Coal Mining Co., Columbus, Ohio. He formerly held a similar office with the Ohio-Saxon Motor Car Co., also of Columbus.

Master
ELECTRICAL PRIMER

Your Cars Need This Now

How quickly does the car start? The answer impresses favorably or unfavorably every prospective purchaser. How economically can it be run? That is another question in every prospective purchaser's mind.

These questions are foremost today because competition and the return of a critical buying public make imperative full returns for every dollar spent.

The Master Electrical Primer provides most desirable economy. It not only affords instant starting, but continued economy of operation through saving gasoline and battery. That is why your cars need this equipment *now—today.*

Its cost is relatively small compared to its value as a sales asset and the good will it engenders in the owners of the cars so equipped.

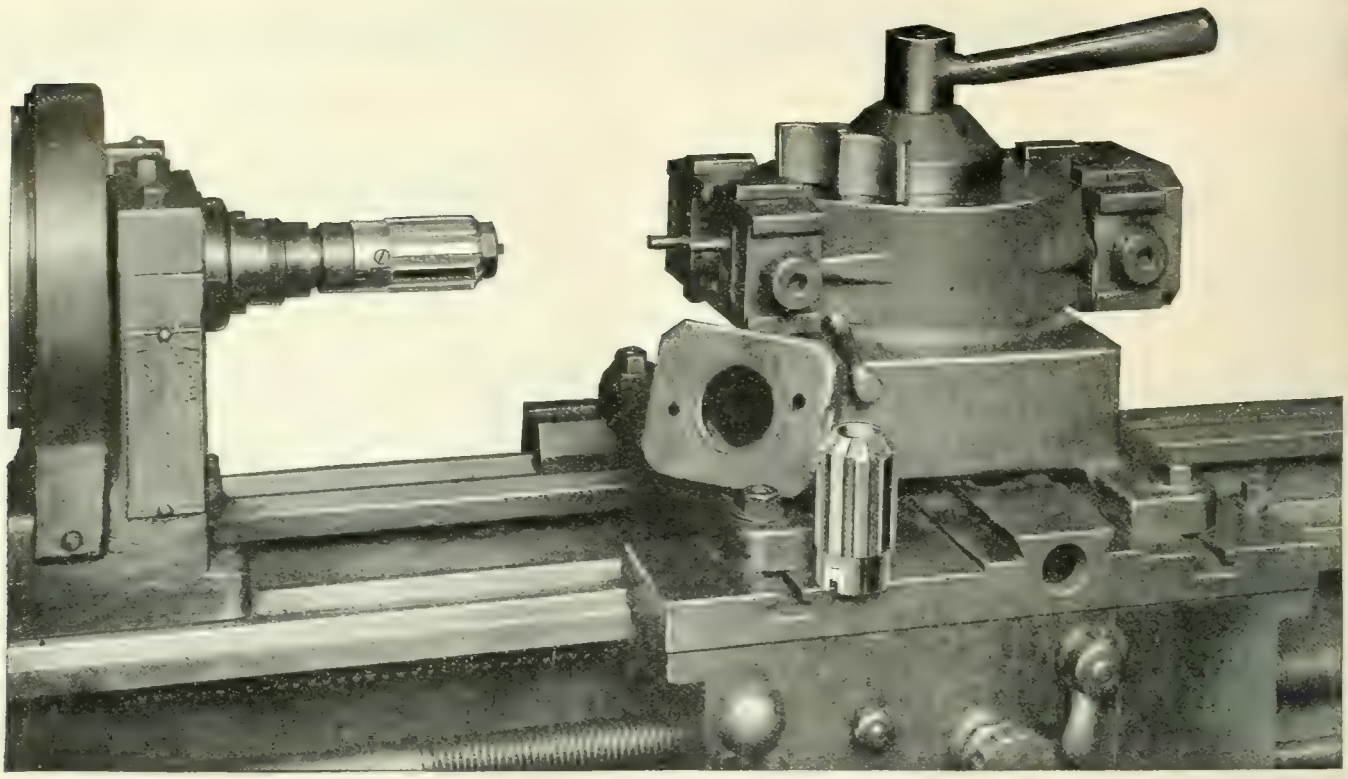
The proven value of Master Electrical Primer is evidenced by its installation as standard factory equipment on the following well-known makes of automotive vehicles:

Franklin ***National***
Cunningham ***Henney Funeral Cars***
Larrabee-Deyo Trucks (Optional)

Master Primer Company

Detroit **Michigan**

Standard Equipment on Quality Cars



Stellite does 22 hours work in a 9 hour day

Using Stellite blades in the above reamer, this manufacturer increased the capacity of the machine from 220 pieces per day to 550, and overcame difficulties and costly delays from blades burning. Stellite's greater speeds and feeds, and longer service to the grind accounted for a production increase of 150%. The operation is boring cast iron Magneto-Pole Pieces in sets, two pieces to a set. Stellite's superiority was established by a comparative time study, as follows:

	Other Tools	STELLITE
Cutting speed, ft. per min.	59	88
R. P. M.	122	180
Feed	.015	.022
Total cutting time	1 min. 6 sec.	30 sec.
Floor to floor	1 " 35 "	59 "
Pieces per grind	100	1000

You may have similar operations in your shop where Stellite would be a vital factor in cutting costs.

THE STELLITE REFERENCE BOOKS explain how to get Stellite results, and our engineers are always ready to further explain or assist without any obligation whatever.

Ask for
VOLUMES 9 AND 10

HAYNES STELLITE COMPANY

Carbide & Carbon Building, 30 East 42nd Street, New York, N. Y.

STELLITE

BAR STOCK

For Tools That Cut at Red-Heat Speed

THE automotive industry recognizes the value and the importance of SPECIALIZATION—of concentration upon the doing of one thing well. It appreciates, too, that the organizations that have done most for automotive progress, have been organizations that have devoted all their skill and energy to bringing individual parts to their highest degree of perfection.

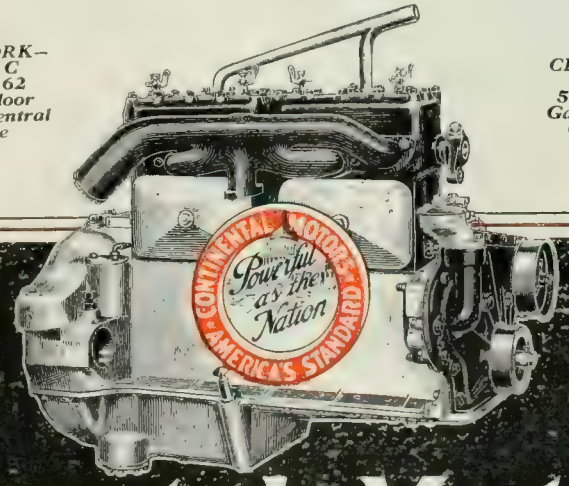
It follows, therefore, that the foremost examples of modern hauling equipment necessarily are SPECIALIZED trucks—trucks that unite the highest attainments of many organizations of specialists working in harmony.

And since these SPECIALIZED trucks are equipped with units made by reputable specialists, it is only natural that dealers and distributors, in increasing numbers, should elect to sell them—should choose to link their own future with the sale of trucks that embody SPECIALIZED units of proven merit—such units, for instance, as the power-plant that bears on its crankcase the ranking insignia of motor-building SPECIALIZATION—the Continental Red Seal.

CONTINENTAL MOTORS CORPORATION
Offices: Detroit, U. S. A. Factories: Detroit and Muskegon
Largest Exclusive Motor Manufacturers in the World

NEW YORK—Booth C 60-61-62 Third Floor Grand Central Palace

CHICAGO—Booths 50 and 51, Gallery of the Coliseum



Continental Motors

VANADIUM

(The Master Alloy)

STEEL

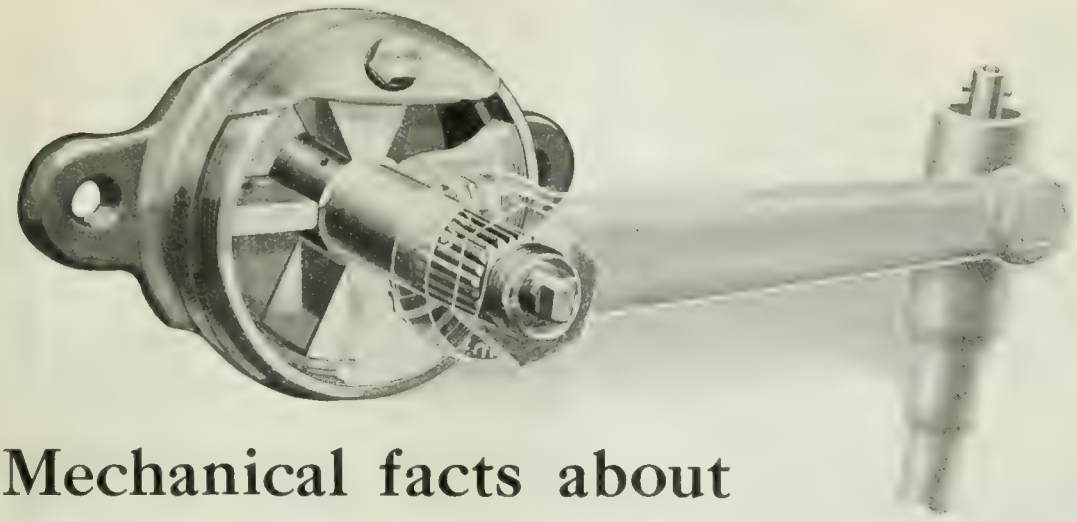
UNSURPASSED

Forgability
Ease of Heat Treatment
Machinabilty
Strength
Toughness
Resistance to Shock and Fatigue

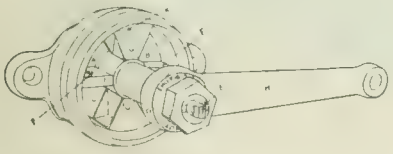
Let our Metallurgical Department help you solve your steel problems

VANADIUM CORPORATION OF AMERICA

120 Broadway NEW YORK



Mechanical facts about THE HOUDAILLE HYDRAULIC (*Say Hoo-dye*) SHOCK ABSORBERS



A & D—Fluid filled chambers—non-compression.

B C—Fluid filled chambers—compression.

F F—Ball valve in stationary wing seating on clockwise stroke allowing fluid to pass only in counter-clockwise direction.

E—Adjusting pin in wing shaft, regulates only channel of flow between chambers on clockwise stroke.

G—Movable wing in wing shaft.

J—Stationary wing.

K—Ball valve in movable wing.

THE Houdaille has two main chambers, the working chamber and the refilling chamber.

The working chamber is divided into four compartments, A B C D, by a fixed wing and a movable wing. The contraction of the automobile spring transmitted thru the link assembly causes a counter-clockwise movement of the movable wing. The fluid flows thru the open valve offering practically no resistance on slight movements, but cushioning severe action. The instant the rebound starts the balls seat and resistance to the clockwise stroke is afforded. The resistance desired is determined by the adjustment of pin E.

The refilling chamber contains a reserve supply of fluid. The action of the movable wing tends at all times to draw in fluid from this chamber to the working chamber thru a ball valve in the flange. Due to the range of adjustment two basic instruments, clockwise and counter-clockwise, will meet any condition encountered in mounting.

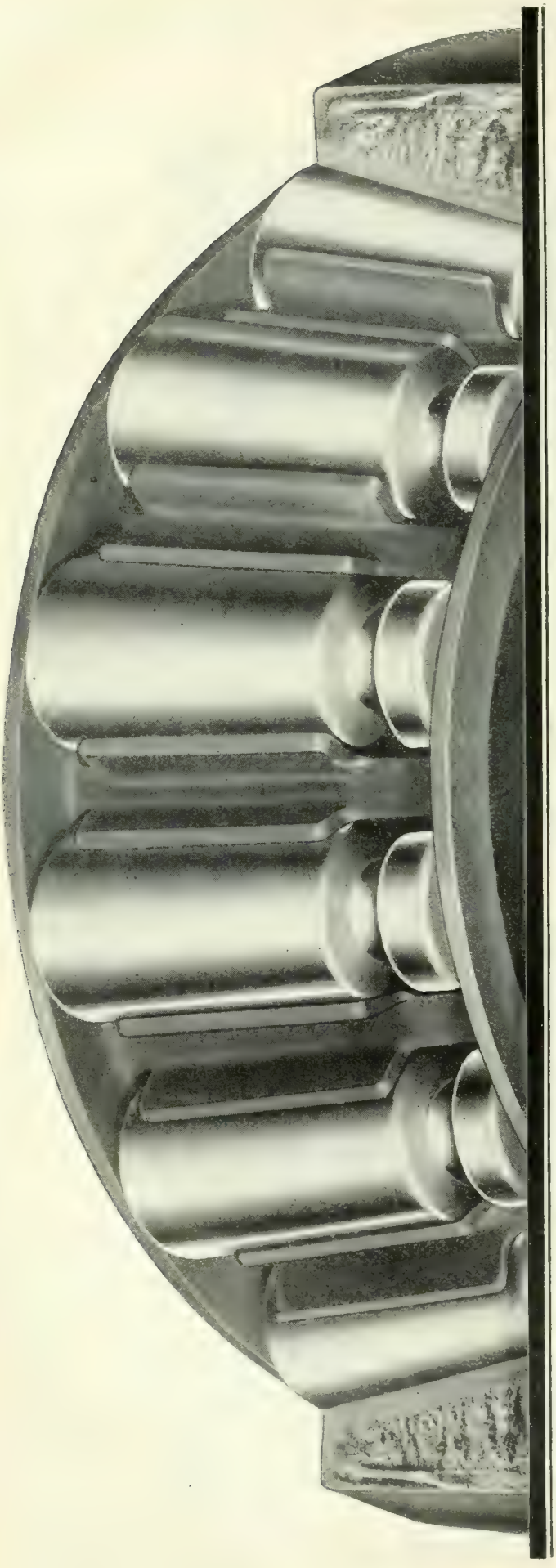
Houdaille simplicity appeals to every engineer—one working part of alloy steel lubricated at all times.

The Houdaille Co.

1435 Root Bldg. Buffalo, N. Y.

Mfg'd by Houde Eng. Corp.

HOUDAILLE
HYDRAULIC
SHOCK ABSORBER



Better Transmissions at Lower Cost

That Timken superior performance may be had in transmission mountings at actually lower cost, is of considerable importance to manufacturers in these days, when every phase of economy is so closely watched.

And when we say lower cost we mean not only in making possible lighter, simpler, and more compact transmissions —(which obviously means a saving of money)—

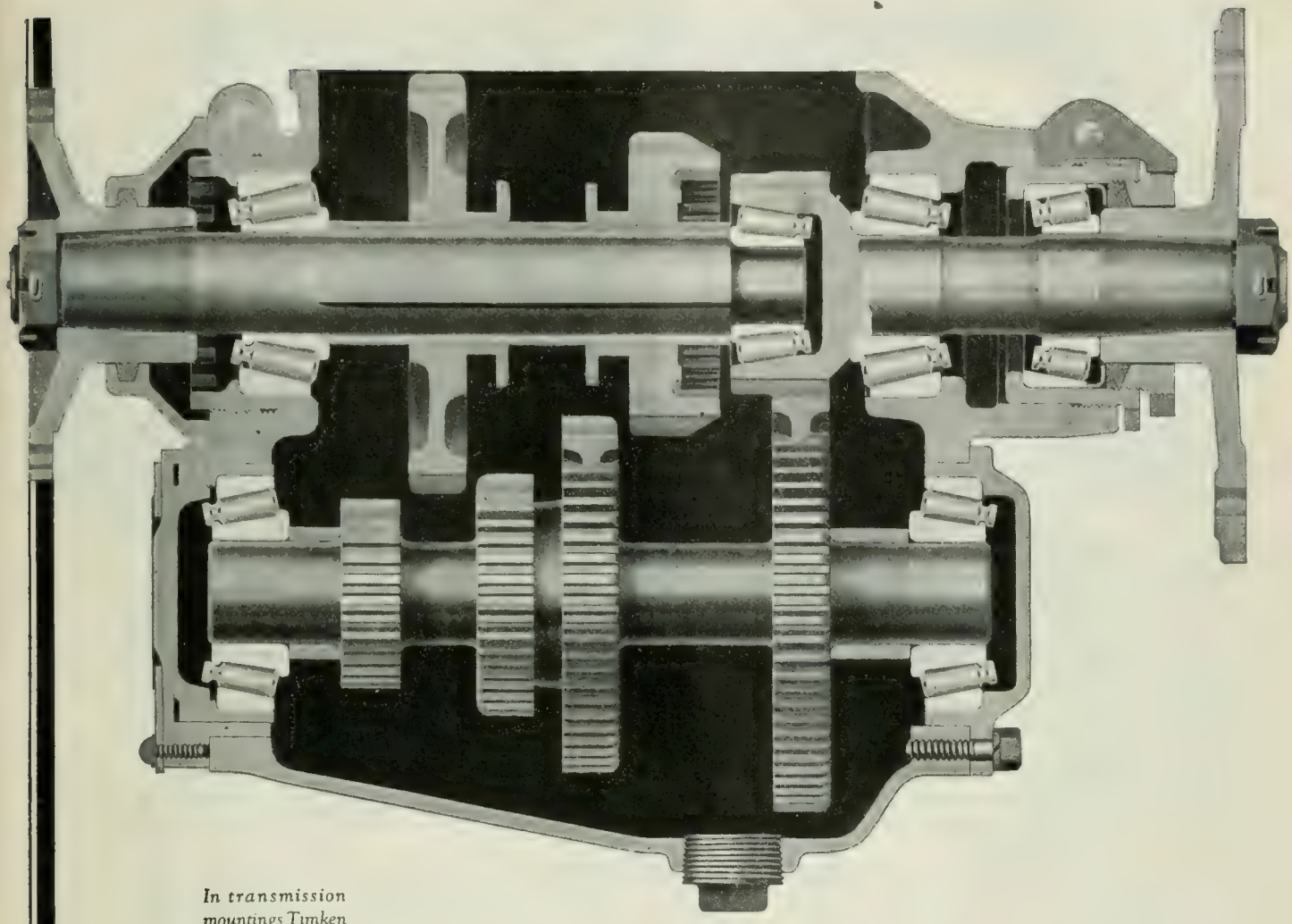
But also an actual saving in the bearing assembly itself as compared with any other type or layout.

Timken superior performance, which is responsible basically for the ever increasing number of Timken-equipped transmissions, means gears held in perfect mesh; shafts kept in perfect alignment; and quietness made permanent—conditions assured because of the ability of Timken Tapered Roller Bearings to carry radial loads, thrust loads, and resultant loads constantly and uniformly satisfactorily, throughout the entire speed and load ranges.

And for further Timken economy remember that when that wear which *must* follow all motion becomes apparent—a simple adjustment and your Timkens function as when new.

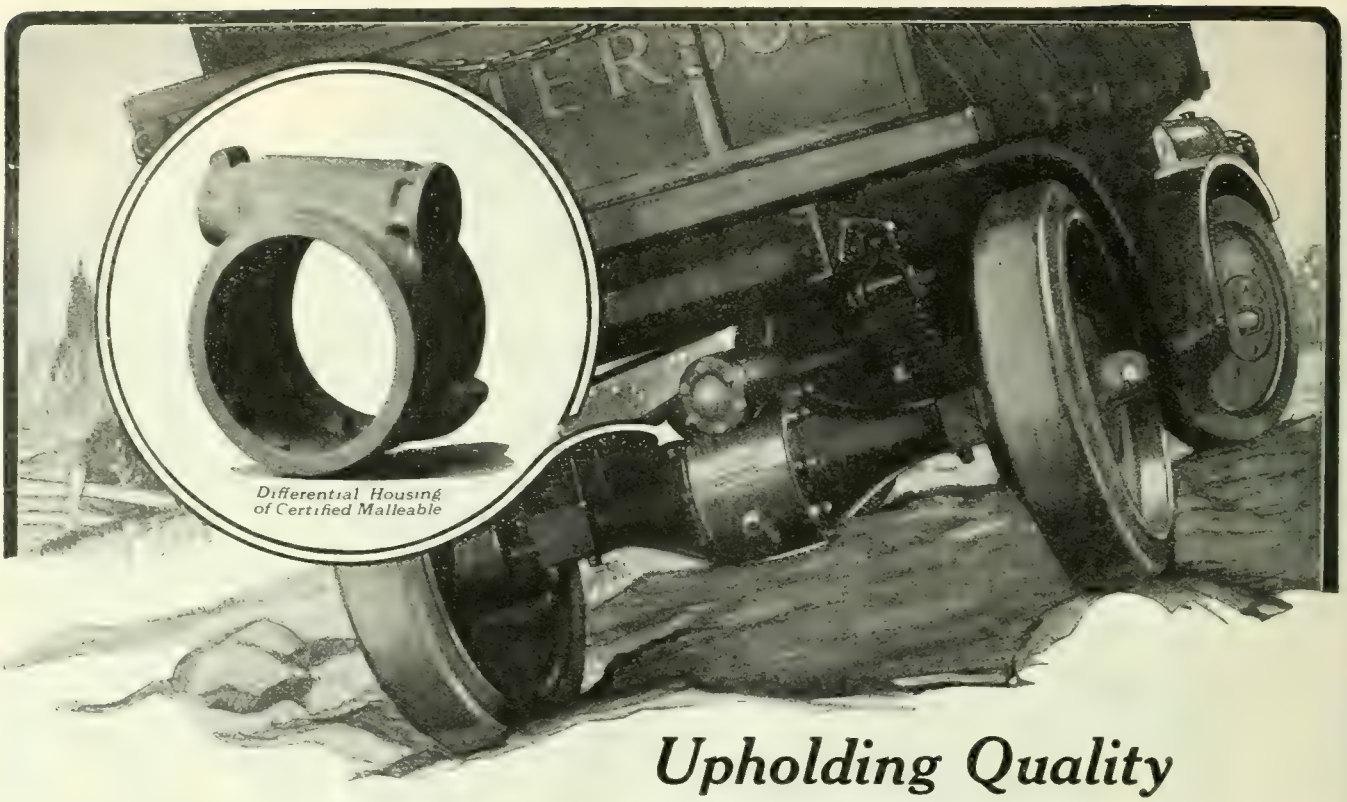
The Timken Roller Bearing Co, Canton, Ohio

Timken Tapered Roller Bearings for Passenger Cars, Trucks, Tractors, Trailers, Farm Implements, Machinery, and Industrial Appliances



In transmission mountings Timken Tapered Roller Bearings successfully withstand the ravages of full motor speed, frequently 3,000 r p m

TIMKEN
Tapered
ROLLER BEARINGS



Upholding Quality with Certified Malleables

Differential housings in trucks and motor cars are subjected to all the violent shocks and strains of motordom. Gigantic engine pull at one end, combined with road hammer at the other, demands material of high quality and integrity.

Housings of Certified Malleable meet these unusual demands. They have the stamina to stand the constant rack and terrific pounding of road service. Great tensile strength, high elastic limit and ductility are superior mechanical properties that insure low breakage, continuous service and long life to all vital parts made of Certified Malleable.

Materials of lower quality jeopardize safety, strength and endurance so necessary in trucks, motor cars and tractors. Certified Malleables are an important part of automotive construction. They uphold the quality, prolong the life, and in every way enhance the value of all products in which they are used.

Plants Awarded Certificates for the Quarter Ending Sept. 30th, 1921

Albany N Y	
Albion Mich	
Marion O	
Lancaster N Y and Owosso Mich	
South Milwaukee Wis	
Racine Wis	
Milwaukee Wis	
West Pullman Chicago Ill	
Cleveland O	
Columbus O	
Danville Ill	
Dayton O and Ironton O	
Kansas City Kan	
Decatur Ill	
Philadelphia Pa	
Erie Pa	
West Allis Wis	
Pittsburgh Pa	
Syracuse N Y	
Warren O	
Syracuse N Y	
Chicago Ill	
Fairfield Ia	
Kalamazoo Mich	
Laconia N H	
Lancaster Pa	
Indianapolis Ind	
Marion Ind	
St Charles Ill	
Cleveland O	
St Louis Mo	
Milwaukee Wis	
Peoria Ill	
Pittsburgh Pa	
McKees Rocks Pa and Hegewisch Ill	
Hillsgrove R I	
Rockford Ill	
Chattanooga Tenn	
St Louis Mo	
Saginaw Mich	
Terre Haute Ind	
South Milwaukee Wis	
Rochester N Y	
Temple Pa	
Terre Haute Ind	
Canton O	
Trenton N J	
E Moline Ill	
Toledo O	
Hoopeston Ill	
Hammond Ind	
Milwaukee Wis	
York Pa	
Zanesville O	

Certificate holders listed here are manufacturers whose product for the quarter indicated has regularly met the requirements of the Association In the judgment of the Association's Consulting Engineer, their plant practice is such as to produce uniform material of high character and integrity.

THE AMERICAN MALLEABLE CASTINGS ASSN.
The 1900 Euclid Building Cleveland, Ohio

EMPRESS

High Pressure Lubricating System

FOR ALL MOTOR CARS AND TRUCKS

A Newer, Better and Simpler System of High Pressure Lubrication

The Empress High Pressure Lubricating System embodies the latest and best features of pressure lubrication for the motor car or truck and at the same time eliminates those objectionable features common to the usual pressure systems; there are no easily mislaid removable dust caps on the connections; no open check valve connections to clean; no flexible hose, no threaded removable or adjustable swivel head to weaken under pressure and leak. The Empress gun and connections are made as nearly accident proof and mechanically perfect as is humanly possible.

The Empress System provides a clean, quick method of thoroughly and effectively lubricating every bearing. With it the entire chassis can be lubricated without the usual muss and trouble and in less than half the time required with any similar system.

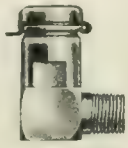
The Empress High Pressure Lubricating System, installed on your car or truck as standard equipment, not only furnishes an easier means of lubricating but protects its reputation —by providing proper and effective lubrication it assures longer life to every bearing.

Write for Descriptive Folder N

Bowen Products Corporation

Auburn Division, Auburn, N. Y.

The necessary pressure is built up in the gun before applying to the connection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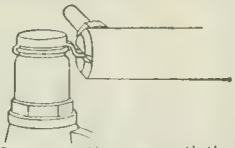
No. 410

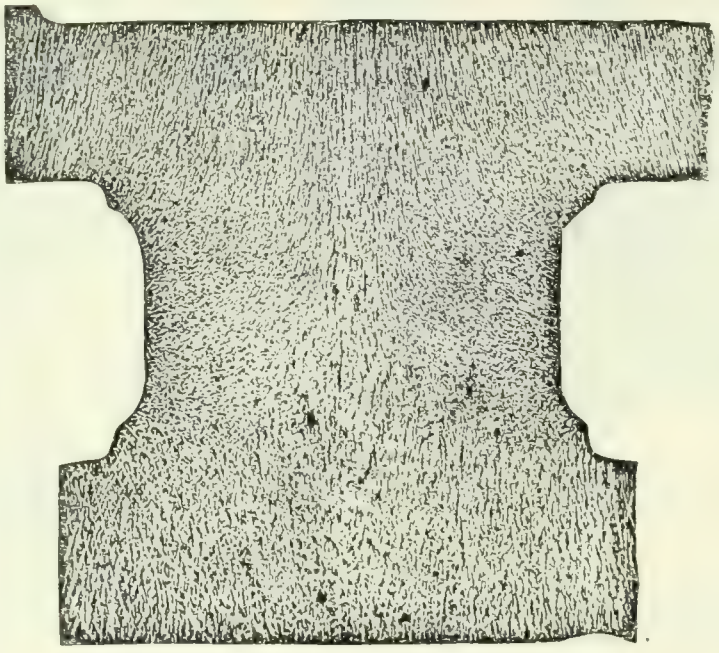
Empress Connections

No. 414


Snap open the cover with the slotted end of the gun, from any position using one hand

YOUR ENGINE'S BACK-BONE

By **DR. LESLIE AITCHISON***



Macrosection of twisted journal of crankshaft.

Position of test piece	Ultimate Strength tons sq. in.	Elongation per cent	Reduction of area per cent
Driving end of shaft (not twisted)	61.8	20.6	56.8
Twisted journals parallel to axis	57.0	3.3	6.0
Twisted journals parallel to twisted fibers	62.5	20.0	57.0
Twisted journals perpendicular to twisted fibers	51.9	0.	0.

"The crank to be considered shows the effects of twisting. The noticeable point, however, in regard to this twisting is that the macrostructure of the dissected journal shows that the twisting has been carried out over a very short length of the journal. Although twisting may be thought quite a harmless operation, yet in view of the profound effect that it has upon the mechanical properties of the steel in various directions (see table of tests), it is advisable to spread the operation of twisting over the greatest length of steel that is possible.

"It was not possible to take impact determinations, but probably these would be found to resemble the figures of the elongation per cent.

"In the specimen under examination, it will be seen that the twisting operation has been carried out on only about one-third of the journal, and therefore the amount of work which has been concentrated upon that part of the journal is very great, whereas the remainder of the journal has been left relatively untouched."

Canton TWISTLESS Crank Shaft Forgings possess a "snaky" grain, i. e., a grain which follows the contour of the shaft from end to end and whose continuity is NOT DESTROYED by any twisting.

We entirely eliminate the twisting operation, and you can incorporate this additional point of technical superiority in your product without increasing your cost.

We are at your service for the asking

CANTON DROP FORGING & MFG. COMPANY

CANTON, OHIO

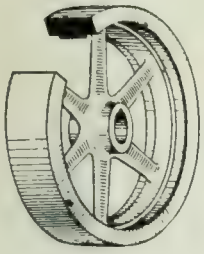
CANTON CRANK SHAFTS

*Extract from paper presented at Midland Institute, Birmingham, England

Proper Distribution of Weight

One of a Series of Talks on Motor Car Construction

By A. L. Putnam, M. S.A.E.



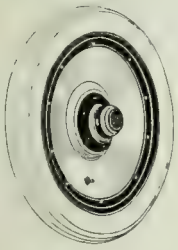
You need only one flywheel on a motor car — not five.

No automotive engineer today would think of putting five flywheels on a motor car—but that is just what the average car has, speaking literally.

The greater proportion of weight in the average spoked wheel is at the rim. The result is a flywheel effect—a weakness which may not be apparent to the layman but which must be admitted by any engineer who investigates the subject.

This construction means greater inertia to be overcome in starting—still more inertia in stopping. It means unnecessary strain on the motor and chassis.

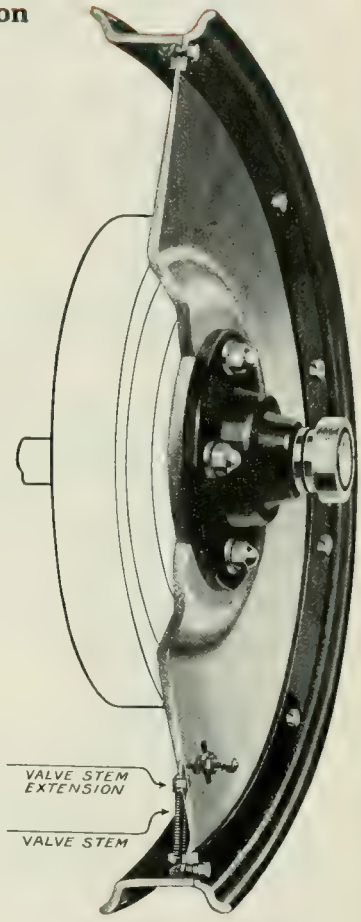
The spoked type of wheel has been with us so long that too many take it for granted. Because it has been used for generations on wagons and other vehicles does not mean it is scientifically correct for motor cars.



Disteels are properly balanced wheels.

In Disteel Wheels, the greater weight is at the hub, where it should be. This is made possible by the tapered disc. Yet, although Disteels are steel discs, they are the lightest wheels made, in relation to their strength and carrying capacity.

It will pay you to give some thought to this question of proper balance in wheels.



Exclusive Manufacturers:

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DISTEEL WHEELS

The Wide Range Adaptability of Hyatt Roller Bearings

The accompanying illustrations show a few of the bearing applications which the Hyatt Roller Bearing Company, cooperating with manufacturers of motor vehicles, have assisted in developing.

The illustrations show very clearly the wide range of uses practical for Hyatt installations.

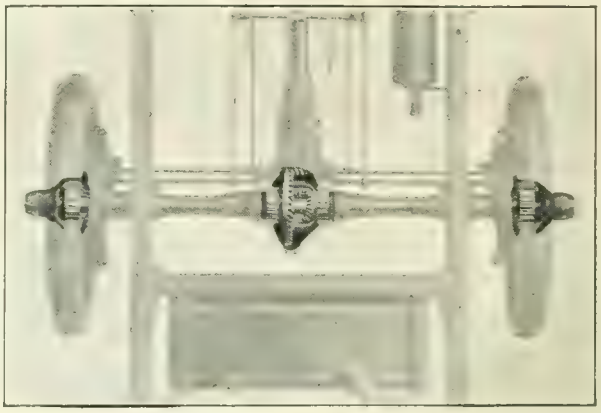
Hyatt Roller Bearings are peculiarly adaptable to simplifying designs. Further, because they can be employed, when desirable, without both inner and outer races, their use constitutes a definite cost saving.

If interested in any of these applications, write for further information. Full data will be supplied you; or, if you prefer, a Hyatt Sales Engineer will call.

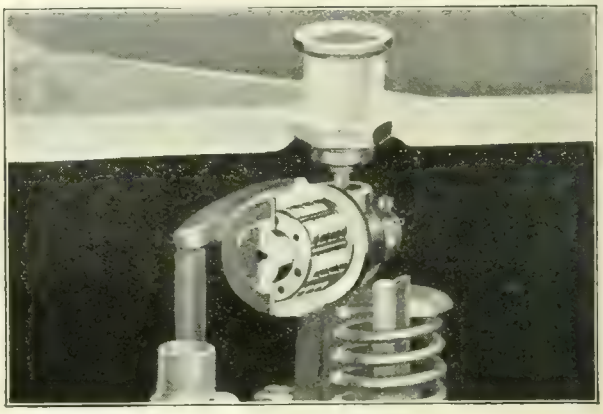
HYATT ROLLER BEARING CO.

Motor Bearings Division: Detroit, Michigan

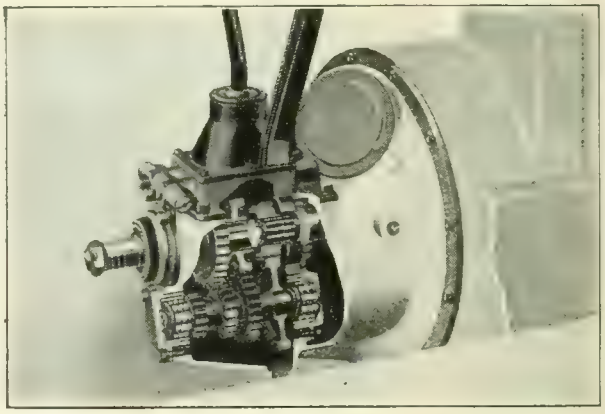
Tractor Bearings Division: Chicago, Illinois
Industrial Bearings Division: New York, N. Y.



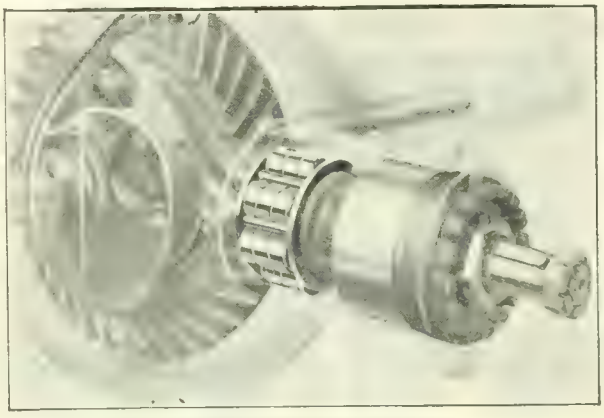
A Sturdy Hyatt-Equipped Axle



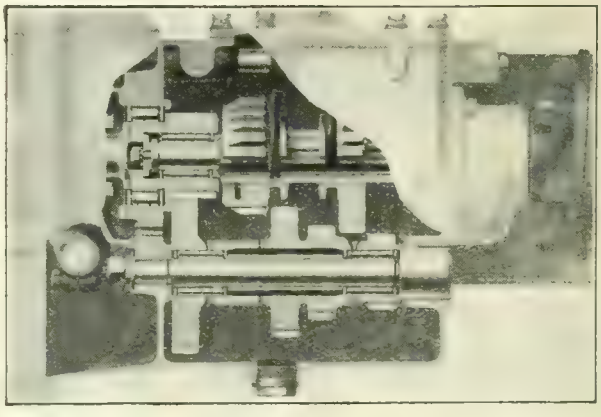
A Hyatt-Equipped Valve Rocker Arm



A Compact Hyatt-ized Transmission



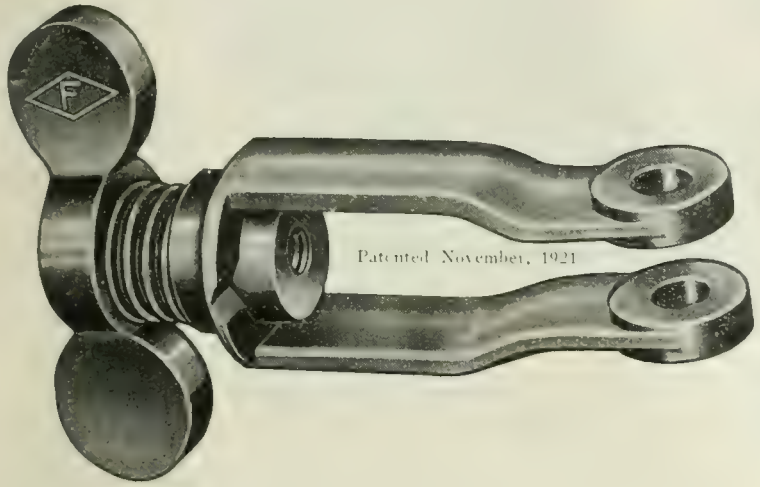
A Hyatt Bevel Pinion Mounting



An Ideal Hyatt-Equipped Transmission

GEMMER Brake Rod ADJUSTER

HAVE YOU TRIED THEM ?



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AUTOMOTIVE Engineers **must** keep up with the rapid developments which are being made daily in car design. The lack of a simple refinement may be the deciding factor in the purchaser's mind which shifts the sale to his competitor. Owners appreciate the little things which make car adjustment a simple detail instead of a major operation.

GEMMER BRAKE ROD ADJUSTERS appeal to the car owner. He does not need a kit of tools to take up brake rods which rattle. He does not need to remove clevis pins, obstinate cotters or check nuts to take up wear. And when the adjustment is made the clevis is automatically locked.

WE want to give you a set for trial on your experimental car. When you have replaced the old yoke and check nut with this simple device, you will understand why they appeal to the car owner.

They Cost No More Than Your Present Turnbuckle Assembly

The Gemmer Adjuster eliminates parts and speeds up assembly on the production line. It is forged; accurately finished and interchangeable with S. A. E. Standard yoke ends and pins.

M. J. Ford Manufacturing Co., 307-11 Newark St., Hoboken, N. J.

Also manufacturers, Standard Drop Forge Brake Levers, machined and in the blank; plain and adjustable yoke ends and brake rod assemblies.

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Information regarding the space available on this page can be secured by addressing the Society.

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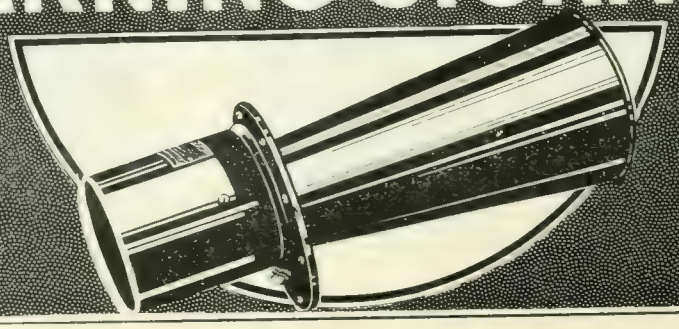

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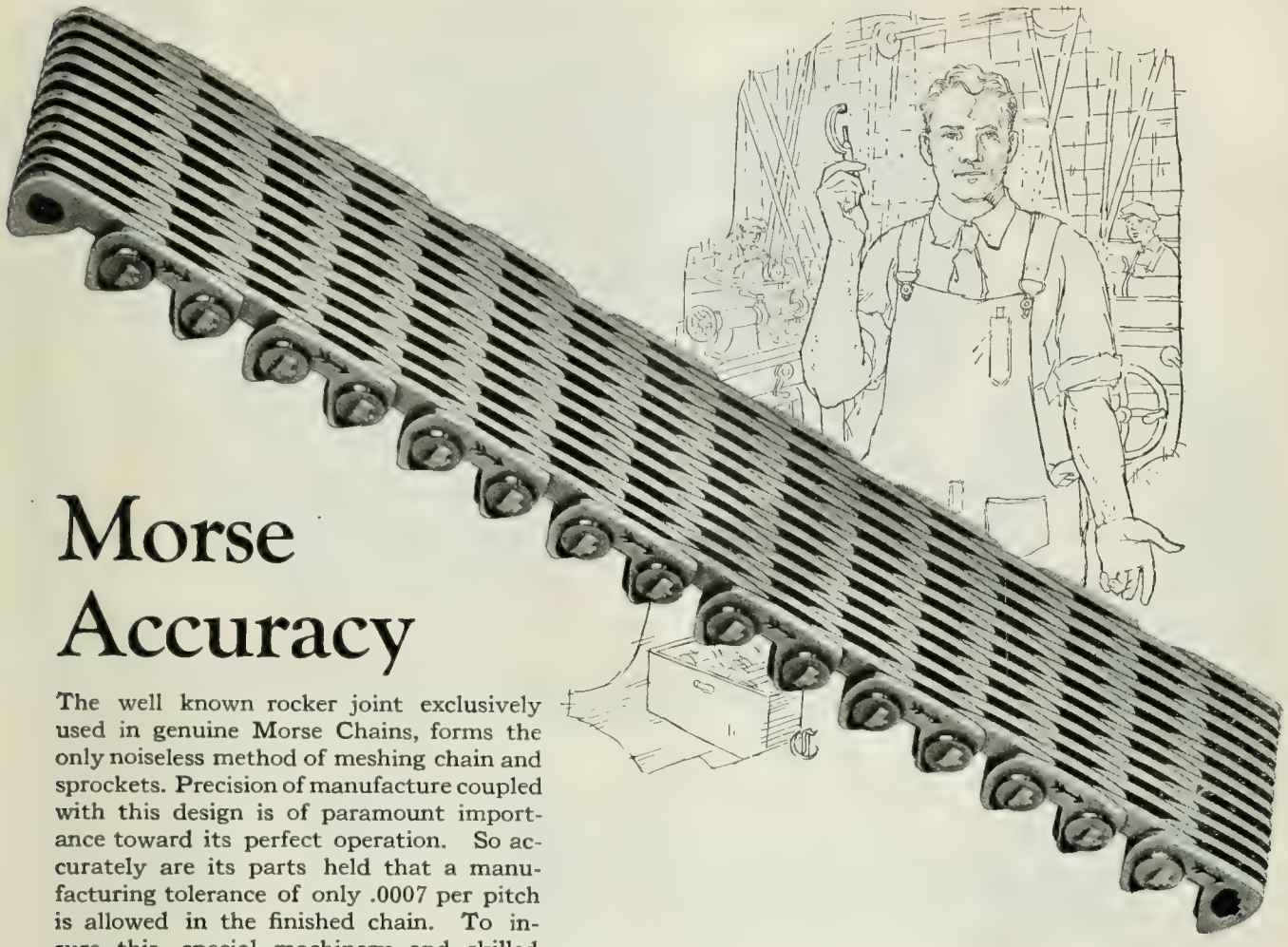

Morse Accuracy

The well known rocker joint exclusively used in genuine Morse Chains, forms the only noiseless method of meshing chain and sprockets. Precision of manufacture coupled with this design is of paramount importance toward its perfect operation. So accurately are its parts held that a manufacturing tolerance of only .0007 per pitch is allowed in the finished chain. To insure this, special machinery and skilled workmen are employed; painstaking inspection and careful selection of materials are maintained.

The same standards of accuracy are held in the manufacture of Morse Sprockets and Morse Chain adjustments. Perfect meshing of chain and sprockets is thus assured, and a Front End Drive produced which operates silently and without friction with the utmost durability.

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ITHACA, NEW YORK

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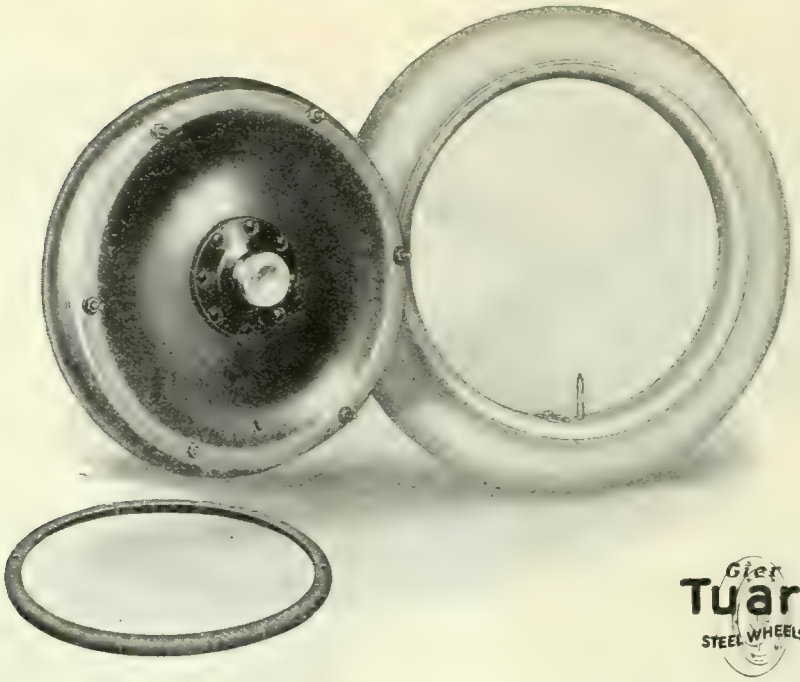
DETROIT, MICHIGAN

MORSE

GENUINE SILENT CHAINS



Gier Tuarc STEEL WHEELS

Definite Advantages for Car Makers and Users

Among engineers Gier Tuarc Steel Wheels have won favor because Tuarc design dovetails perfectly with the original design of the car. No other parts are affected in design or operation by the adoption of Tuarc Wheels.

This means that Tuarc Wheels fit easily into the production routine. Not a single special part is introduced. Even the stock tire carrier serves perfectly because Tuarc Wheels are equipped with regulation demountable rims.

The simplified tire changing is but one of the many practical advantages. The outside position of the tire-valves, the patented clamping ring, the strength and resiliency inherent in the beautiful two-arc design, win the *preference of car buyers* for Gier Tuarc Steel Wheels.

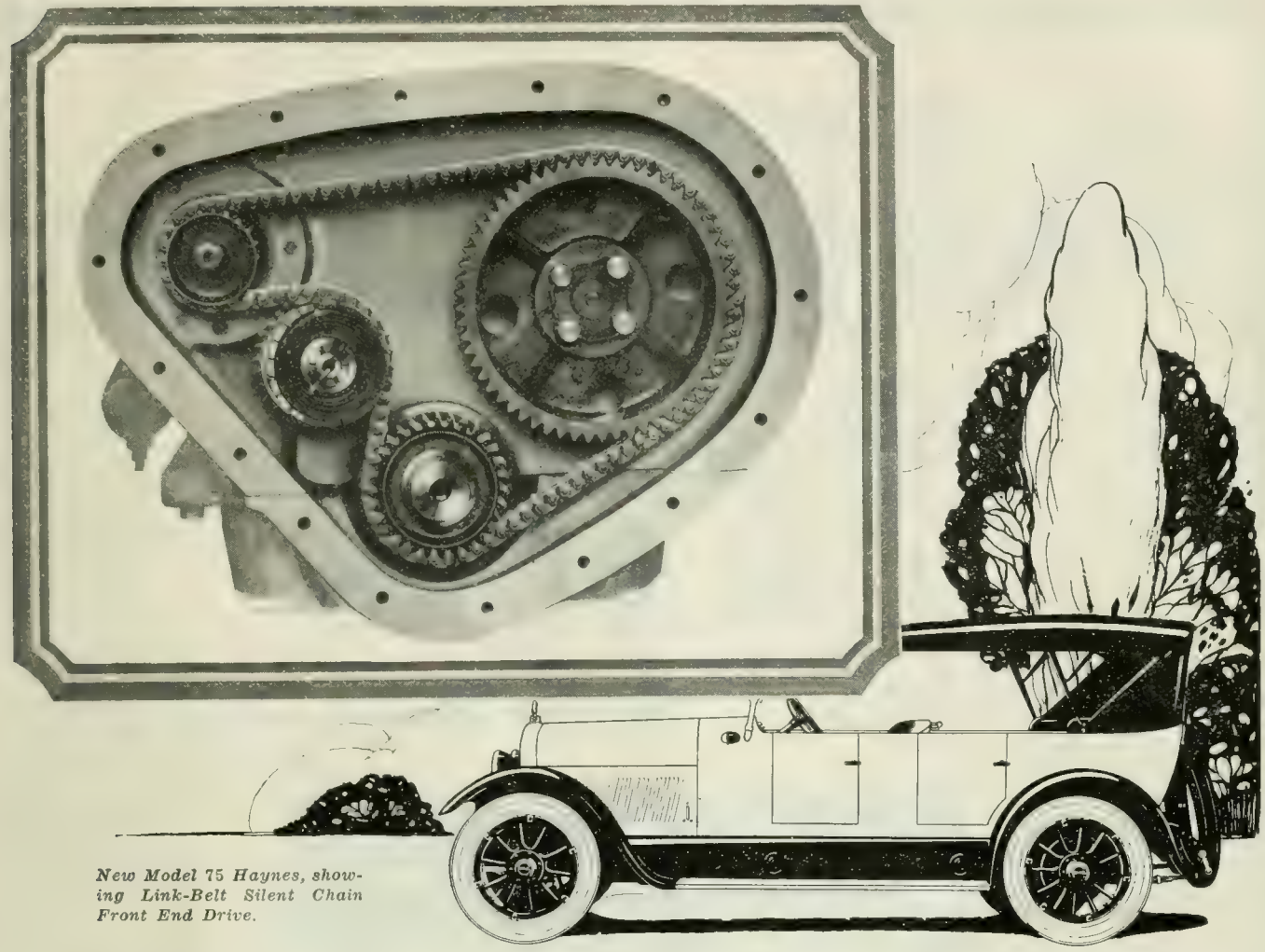
Organizations and individuals capable of handling the wholesale distribution of Gier Tuarc Wheels are invited to make application for exclusive territory assignment.

MOTOR WHEEL CORPORATION, LANSING, MICH.

Motor Vehicle Wheels Complete — Metal Stampings — Steel Products

Motor Wheel PRODUCTS

Gier Tuarc STEEL WHEELS



New Model 75 Haynes, showing Link-Belt Silent Chain Front End Drive.

The Link-Belt Silent Chain Front End Drive on the new Haynes models (see illustration) operates the cam and auxiliary shafts. The chain is of the standard Link-Belt back type (with teeth on both front and back).

The Link-Belt automatic idler, with which the drive is equipped, keeps just the right operating tension on the chain at all times. There is no chance of its becoming loose. The idler acts as a dampener on vibration, maintaining absolute silence in the drive.

The contact of the chain on the crank shaft wheel is more than doubled, preventing the possibility of jumping a tooth in a hasty stop, or under back fire.

The back type chain engages the idler with a positive contact that prevents slippage.

These are advantages that engineers have been seeking for a long time, and this design marks a distinct advance in the art of front end driving.

We shall be glad to send you more detailed information.

LINK-BELT COMPANY 828

West Michigan St. and Holmes Ave. INDIANAPOLIS, IND.

LINK-BELT

Silent Chain Front End Drives

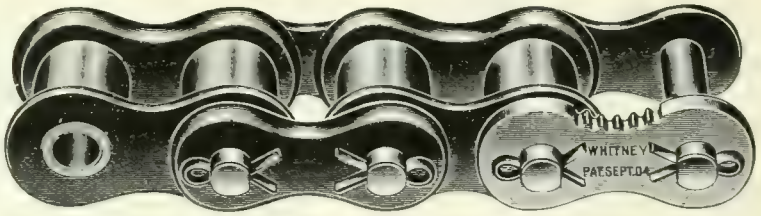
Investigate LATEST

"WHITNEY"

HIGH EFFICIENCY
ROLLER AND SILENT TYPE

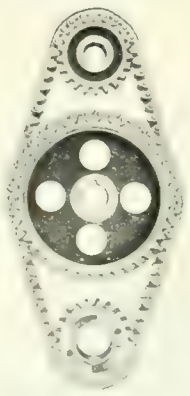
CHAINS

also ***Low*** Cost per ***Thousand Miles*** of Service



LATEST ROLLER CHAINS HAVE SPECIAL QUALITY
SOLID ROLLS AND OTHER IMPORTANT IMPROVEMENTS

Front End Motor Chain Drives



EXCEPTIONAL MILEAGE
AND NEVER KNOWN
TO SKIP THE
SPROCKET TEETH

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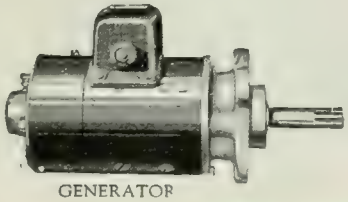
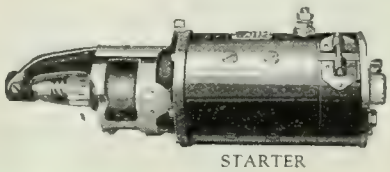
Ignition, Starting and Lighting

Atwater Kent development has kept pace with and frequently anticipated the rapidly changing needs of the automotive industry.

From the beginning of this business, almost twenty years ago, a policy of "quality first" has been maintained. *The result:* appreciation in the shape of hundreds of thousands of factory equipped touring cars, trucks, motor boats, tractors and stationary engines, every one giving that enduring satisfaction that goes with merchandise of quality.



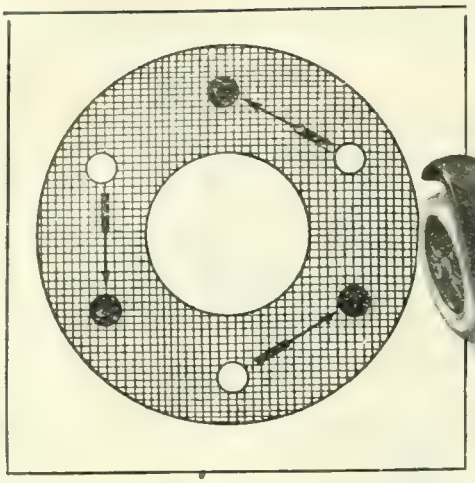
GENERATOR



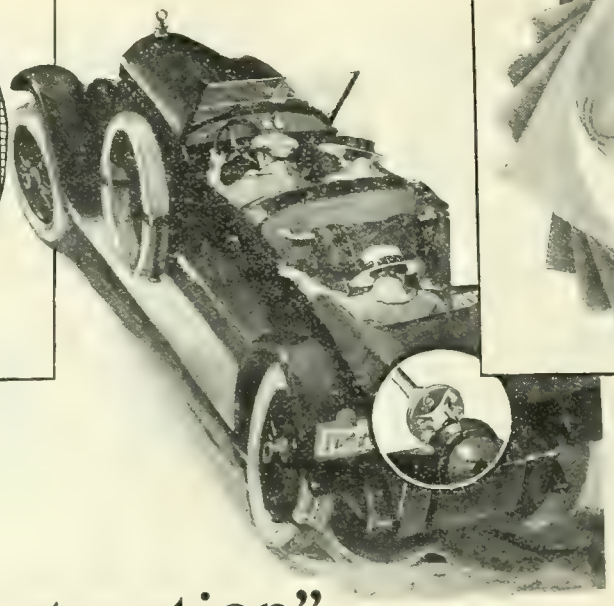
STARTER

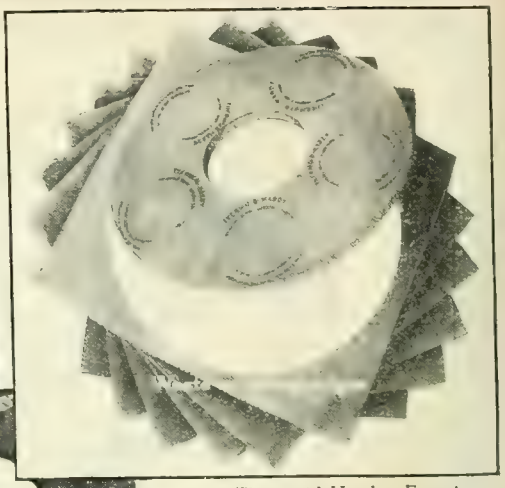
An able engineering corps at your service

ATWATER KENT MFG. COMPANY *Philadelphia*



Ordinary Disc





Thermoid-Hardy Fanwise Construction

"Fanwise construction" in the Thermoid-Hardy Universal

The graphic story of the disc type of universal joint

SEVENTY-FIVE manufacturers have adopted the Thermoid-Hardy Universal Joint as standard equipment on passenger cars, trucks and tractors. As the original disc universal, the Thermoid-Hardy not only has replaced metal joints, but has remained the leader in its field.

The two diagrams above tell the story. At the left is an ordinary disc, its layers of fabric laid parallel. The three black holes are the driving bolts —the three white ones the driven. Notice that the left hand driving bolt is the only one that can pull in the direction of the strands of cotton. The other two must pull on a bias. This stretches the whole disc out of true, causing vibration and whipping of the entire shaft.

In contrast, examine the Thermoid-Hardy patented fanwise construction. Notice how the disc is built up with the strands of each layer of fabric running in a different direction. Each sector is of uniform strength and elasticity. Every stress is balanced

—the torsional stresses between the bolt holes;
—the centrifugal stresses from the center outward;
—the lateral stresses from the forward and back motion of the shaft.

You should have this book—sent free to any engineer

We have prepared a book, "Universal Joints—Their Use and Misuse," that treats the whole subject from all its angles—the mechanical principles involved, construction, lubrication, processes of manufacture, tests for strength, and records of performance. Send for a copy today.

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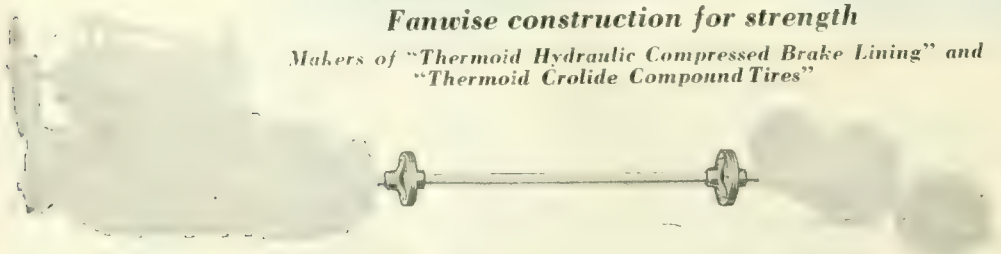
THERMOID-HARDY UNIVERSAL JOINT

Fanwise construction for strength

Makers of "Thermoid Hydraulic Compressed Brake Lining" and "Thermoid Crolide Compound Tires"



List of Users

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Barley Motor Car Co. (Roamer)
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Dart Truck & Tractor Corp
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Mercer Motors Co
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ROME Quality
BRASS & COPPER

BRASS ROD

for grease and oil cups

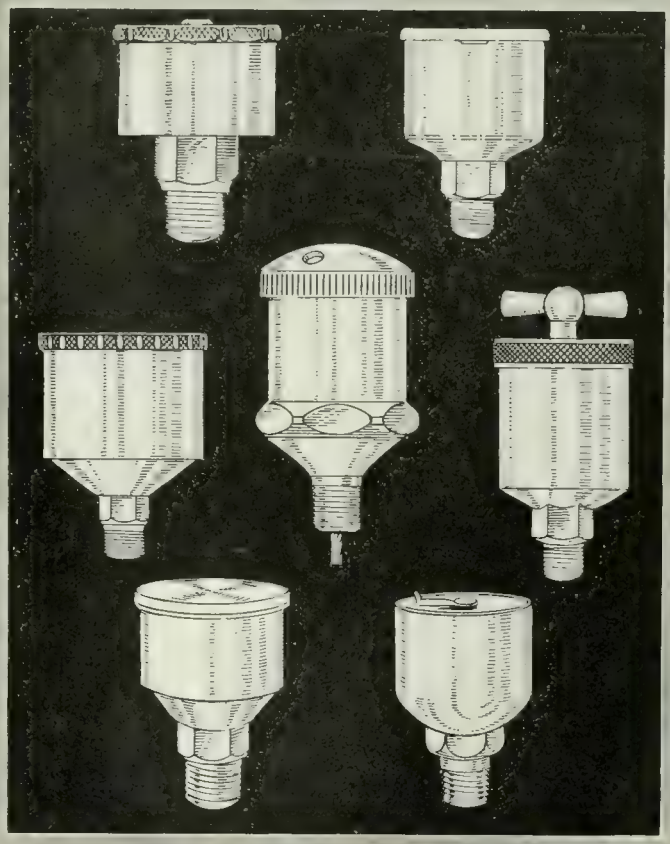
ROME QUALITY Brass Rod is widely used in the manufacture of grease and oil cups. It is free-turning, and thus makes for faster and greater production.

A manufacturer is always assured of uniform metal. He may obtain rod suited exactly to his purpose at any time—if orders are placed regularly or at intervals, the quality is the same.

Rome Brass Rod is furnished in round, square, hexagonal, octagonal, rectangular, half round, and special shapes. It is carefully made throughout and benefits by over 55 years' manufacturing experience.

Rome Quality Products Covered by S. A. E. Standard or Recommended Practices

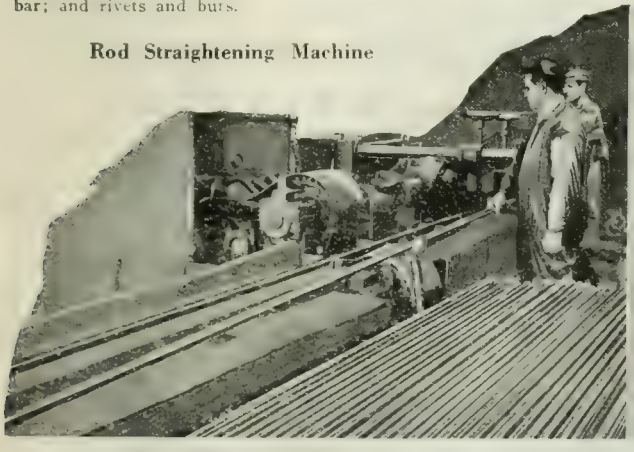
D 57B—Free cutting brass rod and naval brass rod.
D 57D—Annealed seamless brass tubes.
D 57E—Seamless copper tubes.
D 57A—Copper sheets.
D 56 —Brass sheets.

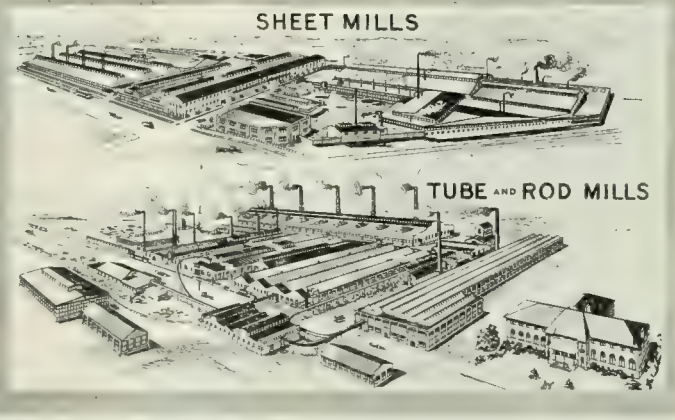


BRASS COPPER BRONZE

Sheets; rolls; rods; anodes; tubes, brazed and seamless; strips; extruded shapes; angles and channels; tapered tubes and hose pipes; door rail; commutator bars and segments; electrical copper bar; and rivets and burs.

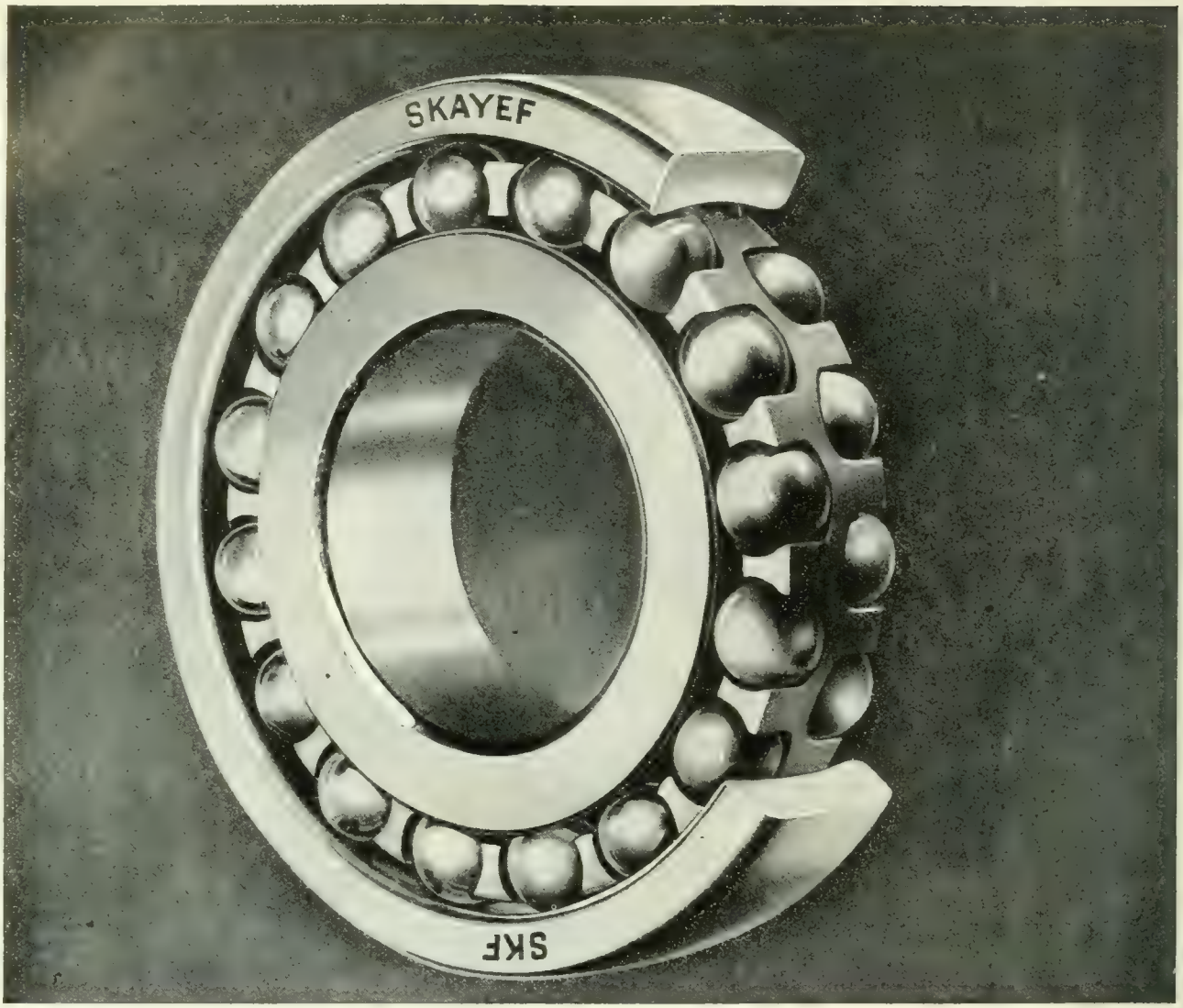
Rod Straightening Machine

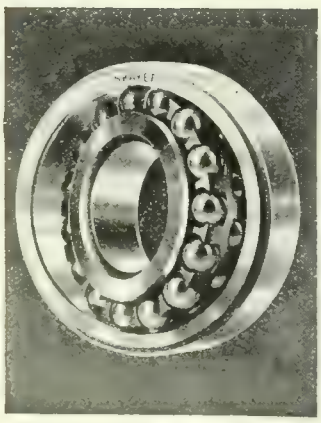




ROME BRASS AND COPPER COMPANY ~ ROME, N.Y.

BRASS ROME COPPER





The modern, highly developed, self-aligning ball bearing

is due to the world-wide studies of SKF engineers, and the experience of The Skayef Ball Bearing Co. These made possible the development of the Self-Aligning bearing, whose special function besides carrying radial loads, is to compensate for shaft misalignment.

The entire engineering experience of our organization is at your disposal. You are urged to submit your bearing problems to us for careful and impartial consideration.

The Skayef Ball Bearing Co.

Supervised at the Request of the Stockholders by

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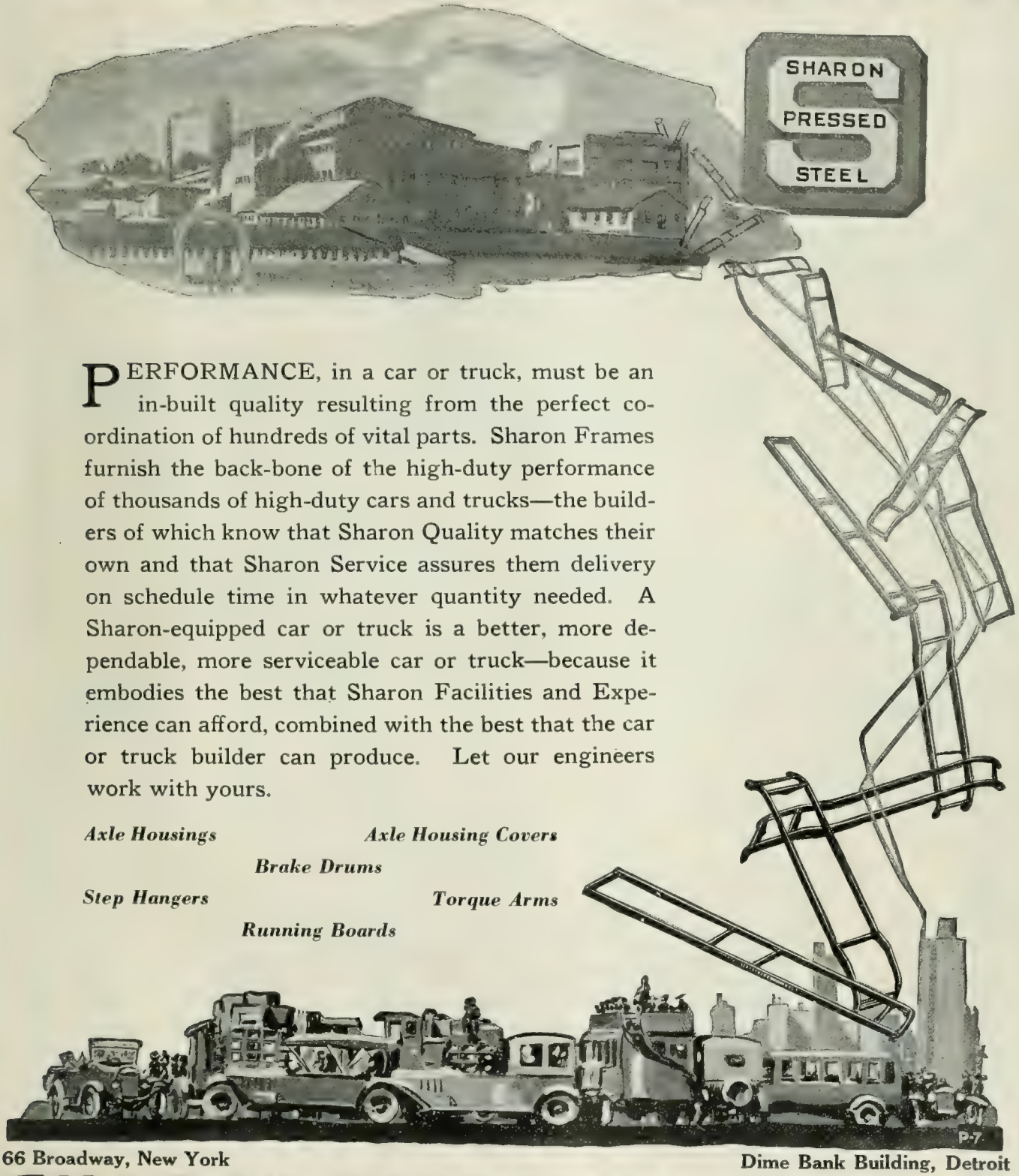
165 Broadway, New York City

624

SHARON FRAMES



PERFORMANCE, in a car or truck, must be an in-built quality resulting from the perfect co-ordination of hundreds of vital parts. Sharon Frames furnish the back-bone of the high-duty performance of thousands of high-duty cars and trucks—the builders of which know that Sharon Quality matches their own and that Sharon Service assures them delivery on schedule time in whatever quantity needed. A Sharon-equipped car or truck is a better, more dependable, more serviceable car or truck—because it embodies the best that Sharon Facilities and Experience can afford, combined with the best that the car or truck builder can produce. Let our engineers work with yours.

Axle Housings *Axle Housing Covers*

Brake Drums

Step Hangers *Torque Arms*

Running Boards

66 Broadway, New York

Dime Bank Building, Detroit

SHARON PRESSED STEEL CO.

MAIN OFFICE AND WORKS, SHARON, PENNA.

RICH TOOL COMPANY

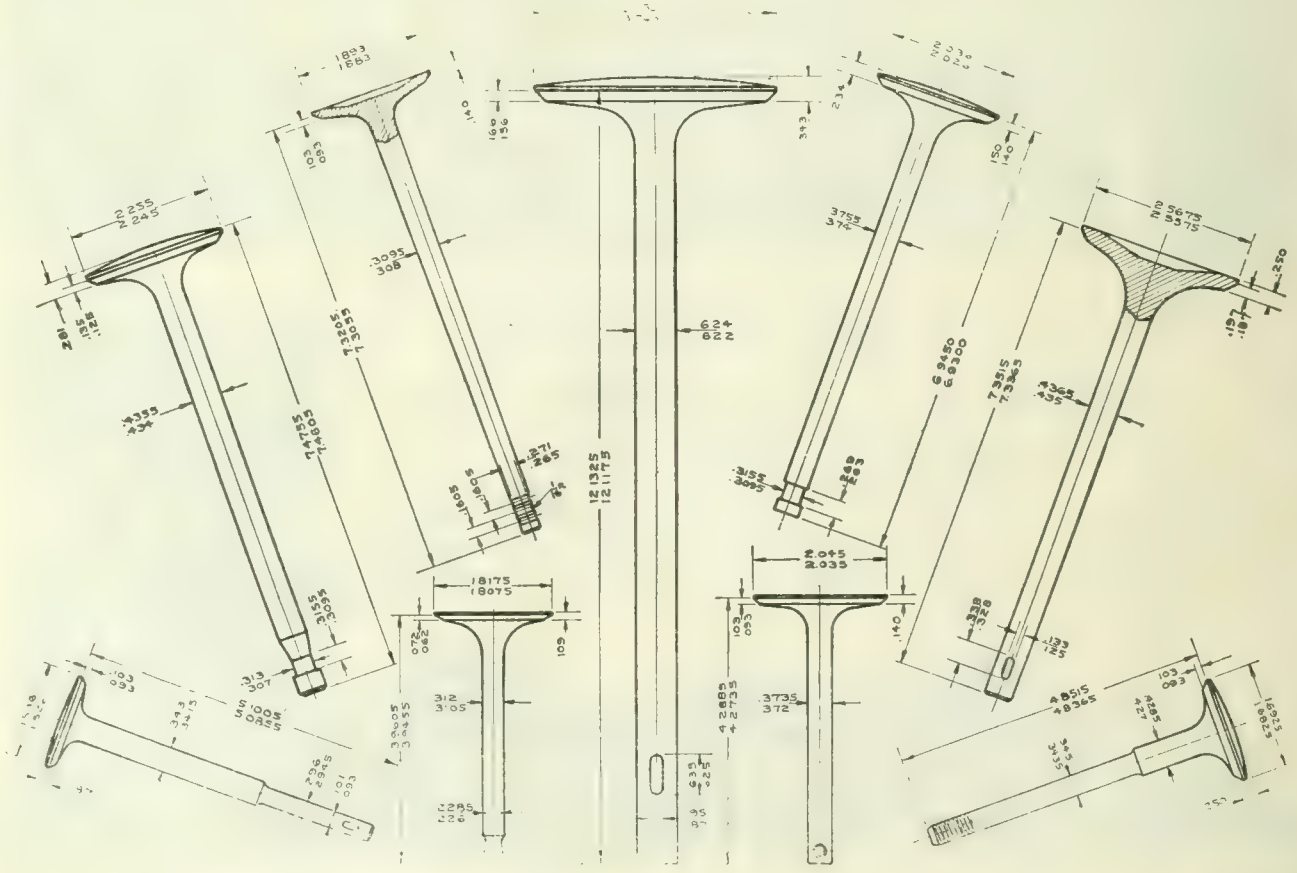
Railway Exchange Bldg., Chicago, Ill. **Kresge Building, Detroit, Mich.**

The cuts below represent valves used in some of the best known present day Aeroplane, Motor Boat and Racing Automobile Engines. They are all products of this Company and most of them have been produced in large quantities and have, therefore, been thoroughly tested in service.

Needless to say, they are all Tungsten Steel, but we also make one-piece forged valves of all other commonly used Alloy Steels, in the manufacture of which we exercise the same care as is used in our Tungsten Valve materials.

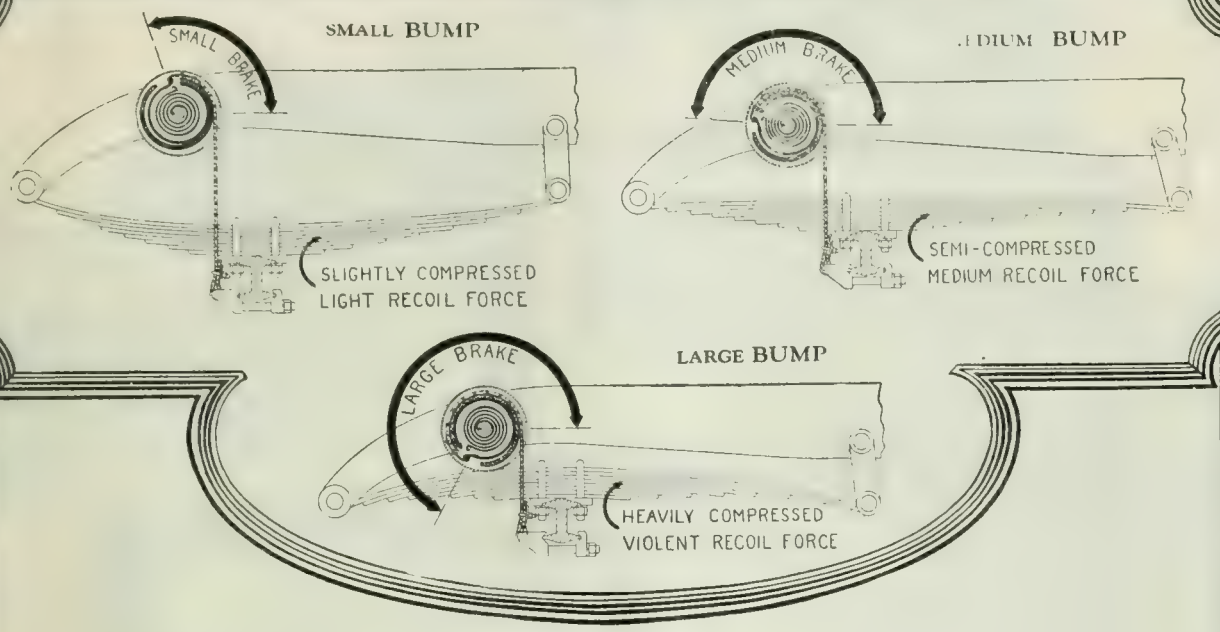
One of the newer types of valves which we have been making in very large quantities for the past two years is our Hi-Chromium Valve, which has some very remarkable properties. It is for some purposes an excellent valve and we solicit inquiries from those who are troubled by a persistent burning away of the seats of the valves in their motors.

We also have a material called Cobalt-Crom that possesses the qualities of High-Chromium as relates to resistance to burning, together with a resistance to abrasion or wear and a strength when red hot more nearly comparable to that of High-Tungsten. This material offers excellent promise of good results in engines running for long periods under heavy load without attention, such as marine motors and tractor motors.



Our Engineering Department is at your service on all questions concerning suitability of material and design.

GETTING RID OF BUMP ENERGY



Isn't it Obvious?

The ***amount*** of bump energy which is momentarily stored in a car spring is determined by the extent of spring compression.

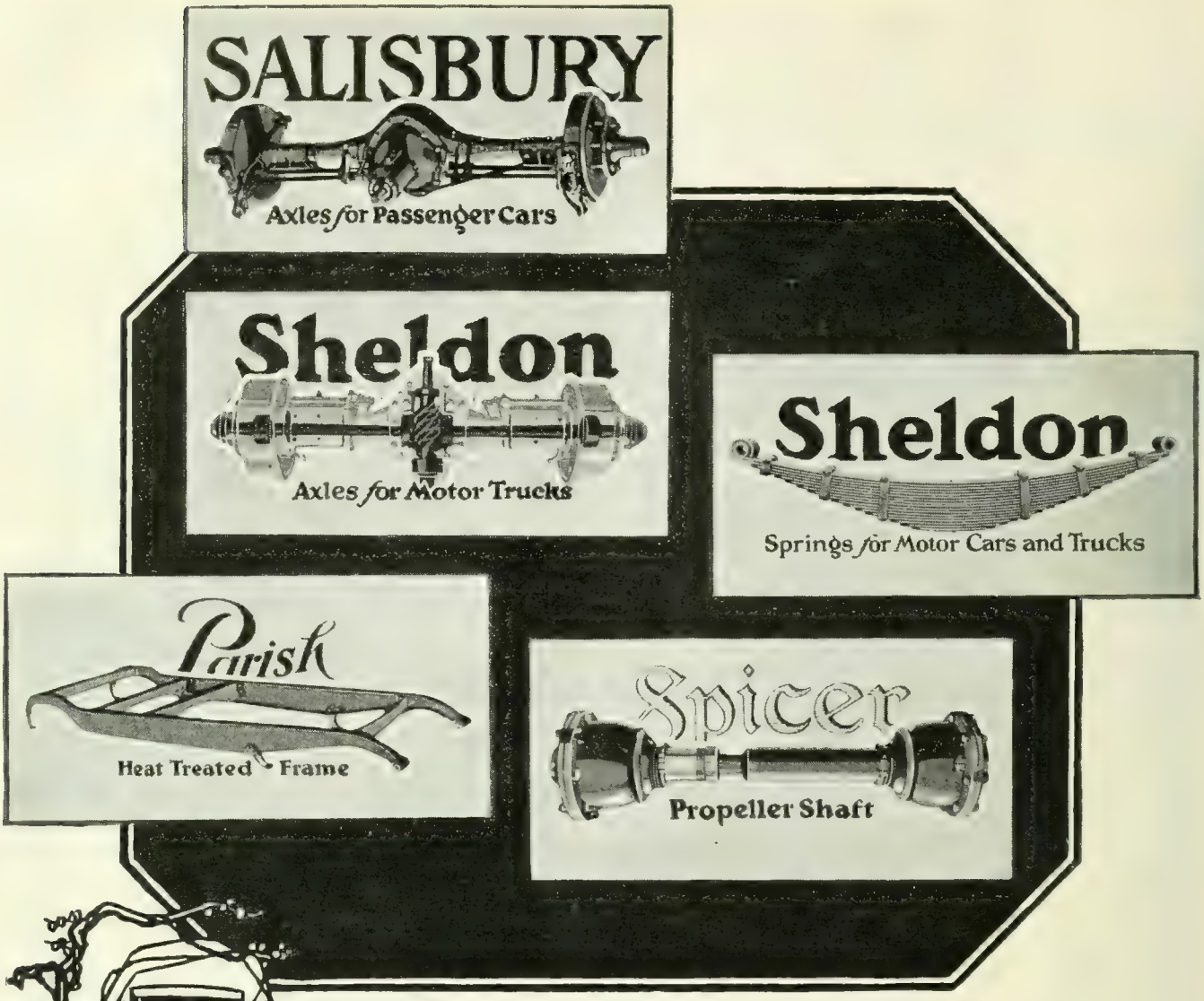
The amount of ***resistance*** which a Watson Stabilator offers to this stored energy, when the spring recoils and unloads the energy at the car body and passengers, is ***likewise*** determined by the extent of spring compression.

Therefore, it matters not whether the bump has caused the spring to be heavily compressed or only lightly compressed—its recoil is in all instances properly harnessed.

This is where Watson Stabilators differ from any other devices on the market. Stabilators check spring recoil ***in proportion*** to the recoil force—thus, for the first time, overcoming the inherent weakness in all makes of automobiles, a weakness which is recognized by all, and is being overcome by the far-sighted car manufacturer. For, even at this early date, Watson Stabilators have been adopted as factory equipment by the makers of some of America's most notable examples of automotive engineering.

JOHN WARREN WATSON COMPANY
24TH & LOCUST STS., PHILADELPHIA, PA.

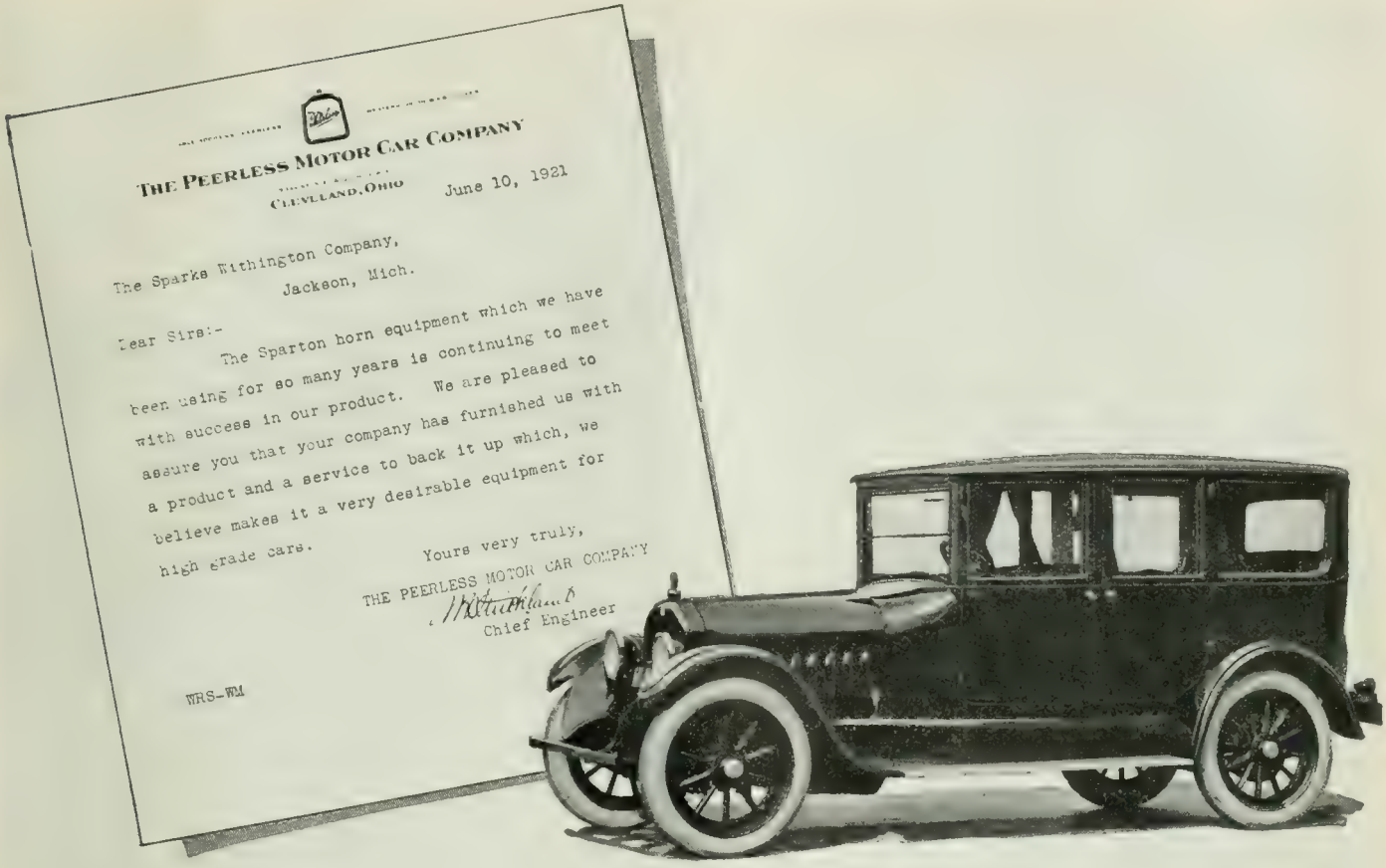
Watson STABILATORS



THE nameplate on a motor car or truck is the manufacturer's own signature—his seal of approval.

It is significant, that so many manufacturers protect their signatures by insisting on having signatures of equal integrity appear on the vital load-carrying parts.

Salisbury Axle Co. - - - - - Jamestown, N. Y.
Sheldon Axle and Spring Co. - - Wilkes-Barre, Pa.
Parish Mfg. Corp. - - Reading, Pa., and Detroit, Mich.
Spicer Mfg. Corporation - - - South Plainfield, N. J.


THE PEERLESS MOTOR CAR COMPANY
CLEVELAND, OHIO
June 10, 1921
The Sparks Withington Company,
Jackson, Mich.
Dear Sirs:-
The Sparton horn equipment which we have been using for so many years is continuing to meet with success in our product. We are pleased to assure you that your company has furnished us with a product and a service to back it up which, we believe makes it a very desirable equipment for high grade cars.
Yours very truly,
THE PEERLESS MOTOR CAR COMPANY
Chief Engineer
WRS-WM

Under the hood of the Peerless is a Sparton Motorhorn

SPARTON
MOTORHORNS

First Choice of America's Best Cars

Ajax	Kissel
Ambassador	Lexington
Apperson	Marmon
Australian (Australia)	Mercer
Bellanger Freres (France)	Merit
Briscoe	Minerva
Cole	Mitchell
Cunningham	Nash
Essex	National
Federal	Northway
F. I. A. T. (Italy)	Packard
Globe	Paige
Handley-Knight	Peerless
Hudson	Roamer
Hupmobile	Sayers-Scovill
Jackson	Service
Jordan	Studebaker
Kenworthy	Tarkington
King	Thomart
	Triangle
	Willys-Knight
	Winton

CLEAR, clean, *resonant* is the voice of the Sparton Motorhorn. Commanding is the warning it speaks.

Not a surly grumble, nor a terrifying screech when the Sparton trumpets its warning, but a rich, stirring note of singular carrying power—an imperative signal to be alert—compelling and authoritative.

Haven't you noticed, for example, that when the driver of a Peerless sounds his horn the warning note is clear, penetrating, and business-like? The Peerless is one of the many fine American cars which are equipped with the Sparton Motorhorn.

The method of outside adjustment is an exclusive feature of the Sparton Motorhorn. Pitch can be regulated by the turning of a single screw. No special tool is necessary—just the edge of a dime.

Sparton Motorhorns—proved in reliability by the unfailing test of years of use on hundreds of thousands of motor vehicles—are available for all classes of passenger cars and trucks.

THE SPARKS-WITHINGTON CO.
JACKSON, MICHIGAN

Manufacturers also of Sparton Fans and Sparton Radiators

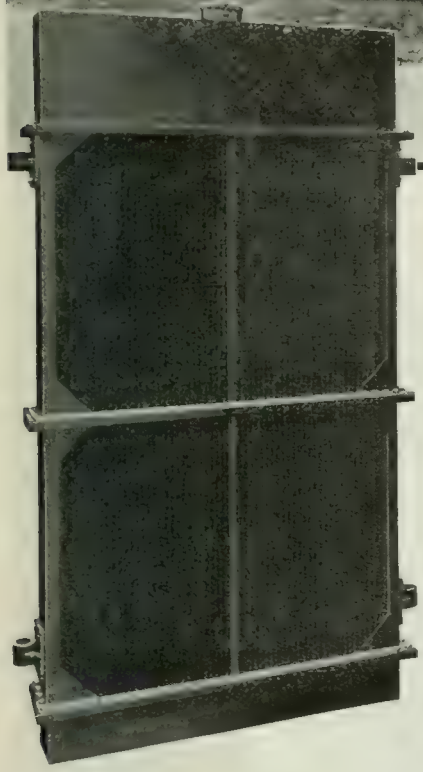
(244)

QUALITY
SNAP RINGS

More Than
a Million a Month

The Good
MAXWELL
is *also* equipped
with Quality Snap
Rings. . . . .

THE Piston RING COMPANY
MUSKEGON, MICH.



Built by the Hall-Scott Motor Car Co. for service on the KowLoon-Canton Railway in China.

Built for Service in China

The efficiency of LONG COOLING SYSTEMS has been an important factor in the building of an international reputation for Hall-Scott Motor Railway Coaches. Their success in this instance constitutes one more proof of their superiority in every branch of the automotive field.

They are standard equipment on so many makes of motor cars, trucks, tractors, gasolene locomotives, railway coaches and other motor-driven vehicles of all kinds that our claim—"The Recognized Standard"—is undisputed.

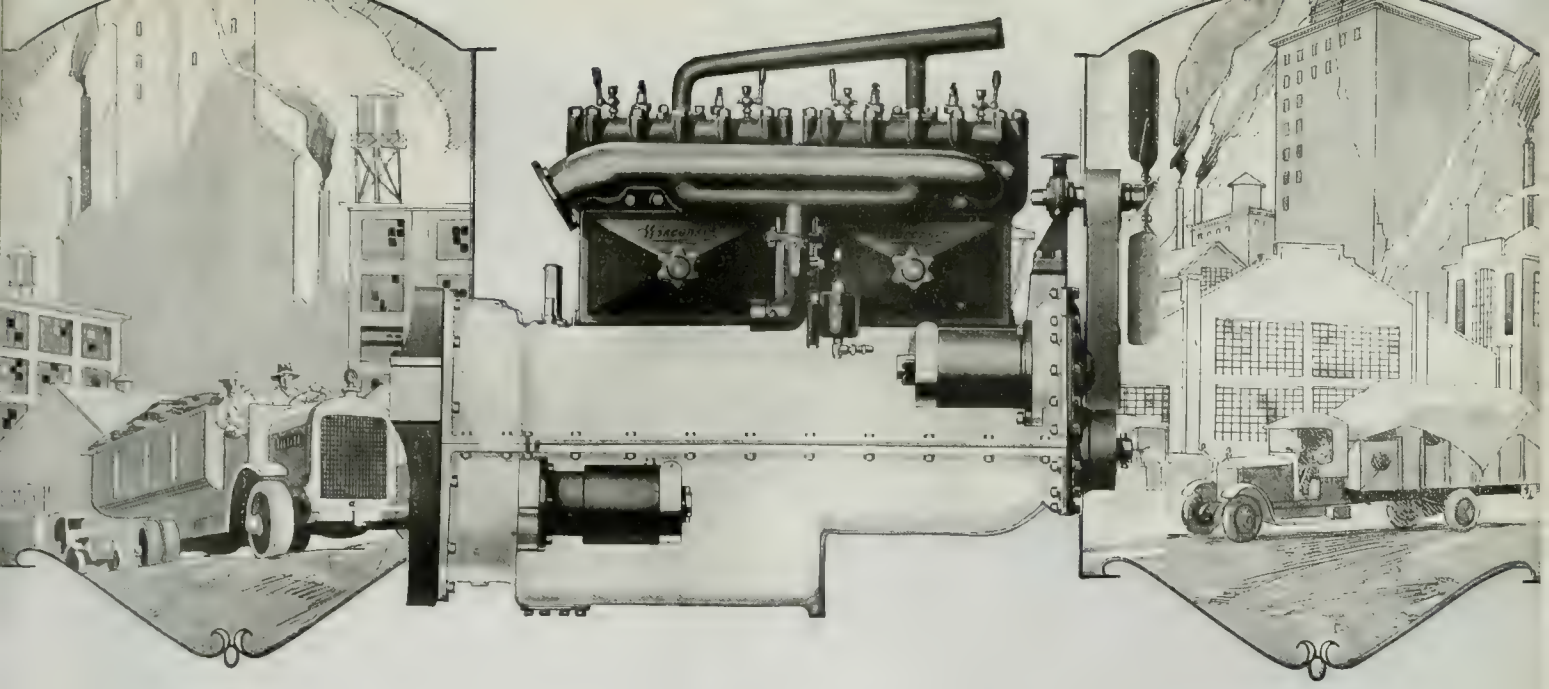
Manufacturers are invited to avail themselves of the cooperation of LONG Engineers when designing new—or correcting unsatisfactory—cooling systems for any motor-equipped product.

LONG MANUFACTURING CO., Detroit, Mich.

LONG
COOLING SYSTEMS

The Recognized Standard for Automotive Equipment

GREATER PRECISION
LESS FRICTION ::
LONGER LIFE ::
ADEQUATE THRUST
CAPACITY
THE FEDERAL BEARINGS CO., INC.
Poughkeepsie, N. Y.
Schatz
"UNIVERSAL"
Registered
Annular
BALL BEARING
Use
a BALL bearing



Building Trucks and Selling Trucks

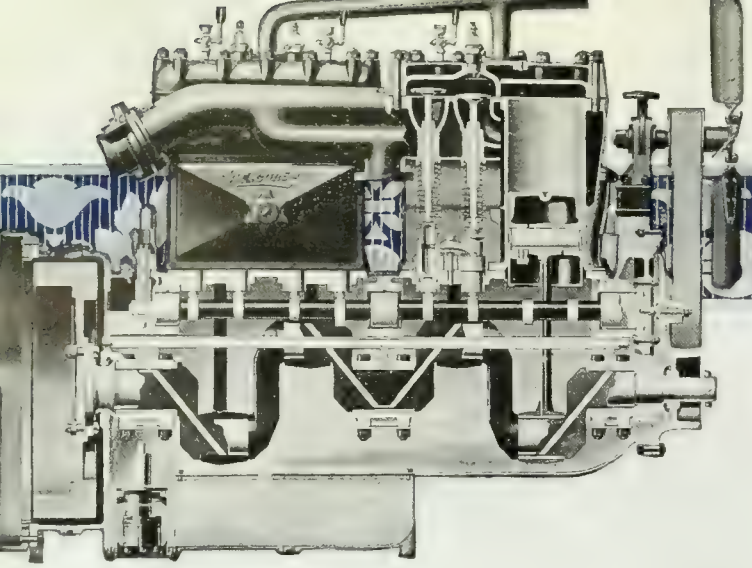
Wisconsin
CONSISTENT

Entering into the manufacture of motor trucks is never a spontaneous undertaking. The period of preparation, the tooling up and analysis of materials, purchasing of parts, and engineering research take months, sometimes years to perfect.

Where outside sources must be depended upon for parts and units, the same scrutiny should be applied to the men and methods responsible for those parts, in order that the finished product may not develop flaws to hinder the sale of the truck.

Manufacturers depending upon Wisconsin Motors to power their trucks have found their choice a good one. The service given by Wisconsin Motors—especially in the accomplishment of unusually hard duties—has made the reputation of every truck in which they are used. The buyer of a truck that carries a Wisconsin Motor finds a new significance in the power of his dollar to procure bigger and better value.

The nameplate on a truck can be made a bigger asset with a Wisconsin Motor under the hood.



"What Motor Has It Got?"

Wisconsin
CONSISTENT

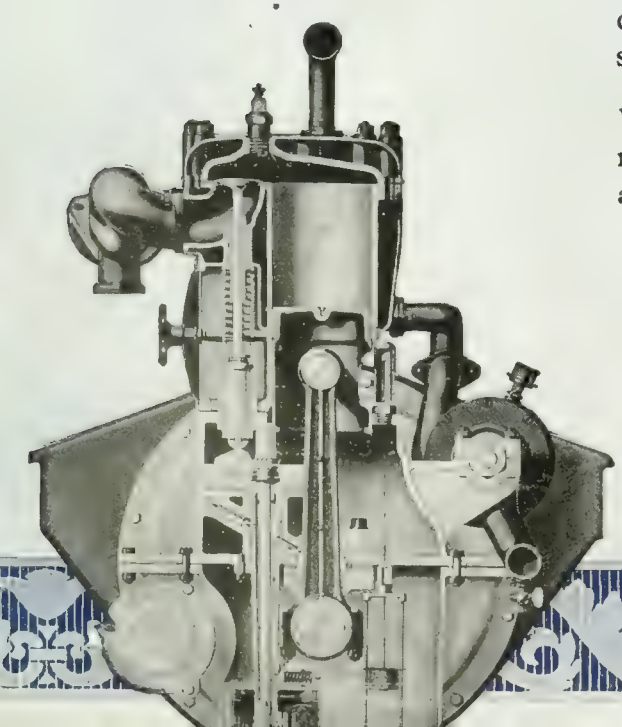
DISTRIBUTORS

T. M. FENNER
21 Park Row, New York City

CHANDLER - HUDSON CO.
Seattle, Washington

WISCONSIN MOTOR PARTS CO.
2354 Cottage Grove Avenue
Chicago, Illinois

EARL P. COOPER COMPANY
1310 South Los Angeles Street
Los Angeles, California



When a User talks favorably of your product he is your salesman, building good will and profits for you.

The buying public has been educated by manufacturers to know that assembled products shall not only be good as a whole, but that they shall be good part by part to give satisfactory results.

Motor car, truck and tractor buyers are the best example of this class of buyers. Invariably the first question concerns the motor; then the other parts, but always the motor first.

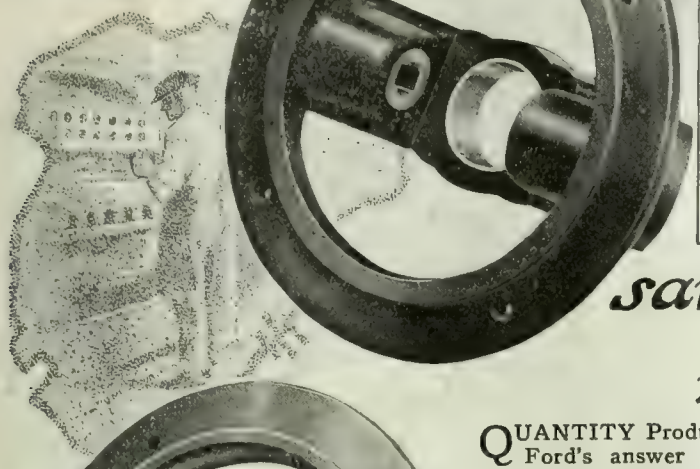
There is a convincing story in Wisconsin Motors, their history, their achievements and their wonderful record in every service—a story that closes the business because so few others can claim such a right to the consideration of the careful buyer.

Wisconsin Motors go out first and come in last; their reputation is for consistency and utter dependability—assets of untold value in merchandising.

WISCONSIN MOTOR MFG. CO.
MILWAUKEE, WIS.

BAKELITE

REG. U.S. PAT. OFF.

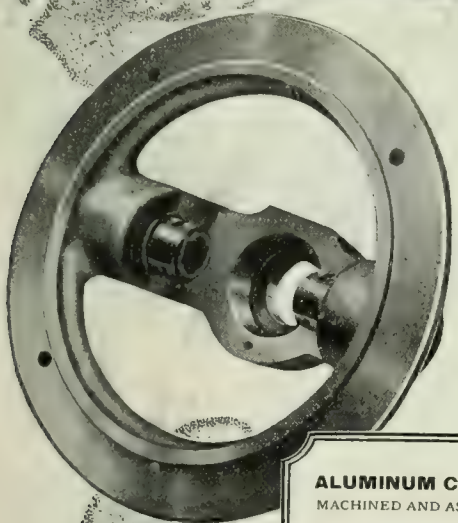


MOLDED
BAKELITE

1. Placing Metal Inserts in the Mold
2. Weighing BAKELITE Molding Material
3. Filling the Mold
4. Molding
5. Removing the Finished Piece

Estimated time, quantity production, *including hardening in the mold* — 7 minutes

saved the difference in time alone—



QUANTITY Production was Henry Ford's answer to Hard Times. Greater Output means a lower manufacturing cost per item—smaller selling price—larger sales volume—*increased profit.* This may look like a long way 'round, but it's really a short way *home.*

A few years ago, Gilfillan Bros., of Los Angeles, Cal., entered the field with a portable electric drill. It was a good drill, and they sold a lot of them; but it wasn't up to their ideals because it wasn't light enough.

They made it of metal throughout. You can get an idea of some of the work involved by looking at the aluminum brush holder frame reproduced at the left. Quantity production, on turret lathes, had cut down the working time to approximately 23 minutes for this piece, but *that* depended on the human element, and did not include hardening in the mold and transfer from one department to another.

Bakelite solved their problem. Look at the same piece, molded in 7 minutes, which includes hardening! This piece is begun and completed in the molding presses. It is *finished,* even to the high gloss, in this one department.

Seven metal inserts, incorporated in the Bakelite, are turned out by automatic screw machinery. This is *only one more* special part than was required for the aluminum frame. Bakelite itself, being a high dielectric, the insulating bushings required between the brush holders and the *metal* frame are now eliminated.

Have *you* considered Bakelite? Have you thought it too expensive? Gilfillan Bros., in a highly competitive field, didn't find it so.

Why not let us go into details with you?

ALUMINUM CASTING
MACHINED AND ASSEMBLED

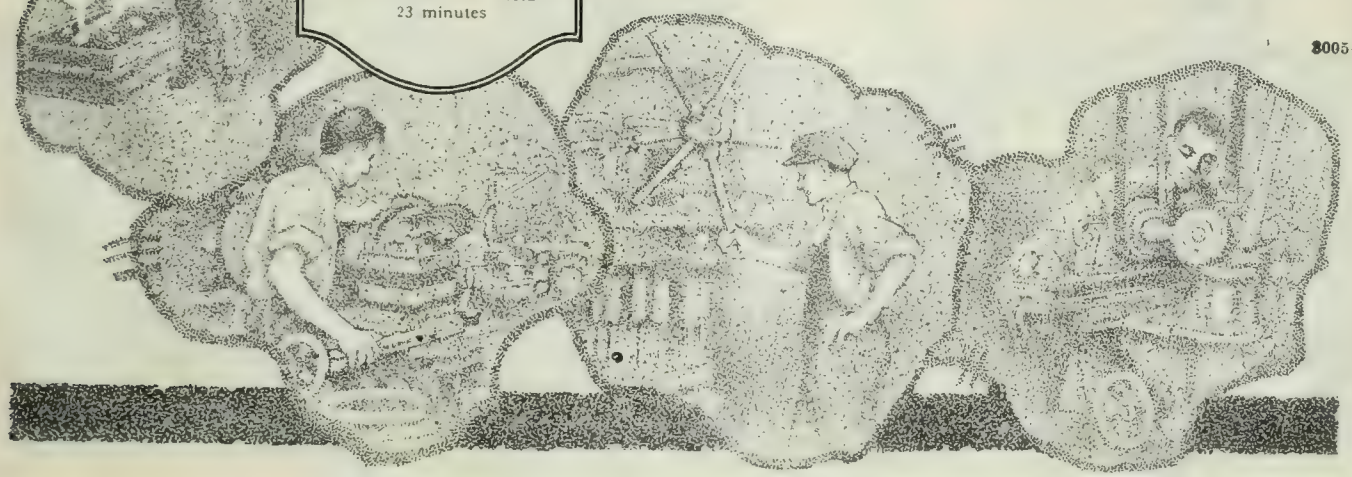
1. Making the Mold
2. Pouring the Metal
3. Breaking the Mold
4. Cleaning the Casting
5. Machining—8 Surfaces
6. Slotting
7. Drilling—7 Holes
8. Tapping—2 Holes
9. Assembling

Estimated time, quantity production, but not counting hardening in the mold — 23 minutes

GENERAL BAKELITE COMPANY
Two RECTOR STREET, NEW YORK, N. Y.

We welcome inquiries from manufacturers and maintain a research laboratory for the working out of new applications.

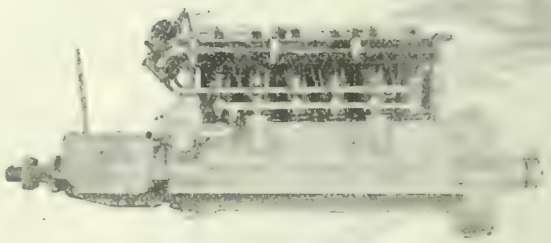
8005-R



Three New World Records!

The Nick Nack, powered with a six cylinder, 200 H.P., Hall-Scott engine, smashed three world records for runabouts with marine engines, in the Wood-Fischer race at Detroit, August 27-30. The three new world records are: lap or 2½ miles at speed of 42.15 M.P.H.; 50 miles in 1 hour, 12 minutes, and 31 seconds—average of 41.3 M.P.H.; 150 miles in 3 hours, 41 minutes, and 13 seconds—average of 40.6 M.P.H.

AT NO time during the three gruelling heats of the Wood-Fischer race was it found necessary even to lift the hatches of the Nick Nack. Beneath these hatches, a Hall-Scott marine motor functioned perfectly, just as expected, during every second of the 150 miles.



Mogul Motor Bearings, too, functioned as expected in this famed marine engine, just as they always function in all Hall-Scott marine and aeroplane engines. Mogul bearings stand such exceptional wear and severe strains because they are built to meet them. Virgin metals—scientific selection and preparation of the correct formula—thorough mixing and refining methods—special processes insuring bearings with a solid, closely-knit grain, free from blow holes or porosity—all this, plus 100% inspection throughout the course of production are some of the main reasons why the Mogul trade mark on a bearing is an absolute guarantee against all trouble.

For 25 years we have manufactured bearing alloys, and for 15 years we have specialized in motor bearings. Surely the benefit of that experience can be of value to you. Let us make your test sets and help solve your motor bearing problem.

MUZZY-LYON COMPANY
DETROIT MICHIGAN

Mogul
Bearing Alloys *and* Finished Bearings

Westinghouse

STARTING, LIGHTING & IGNITION EQUIPMENT

Morale

When a Service Department distributes a large number of branches over a wide territory, something very definite has to be done to maintain the spirit of the parent organization in these branches.

This can be built up only by close personal contact between the Home Service Department and the Branch Representatives.

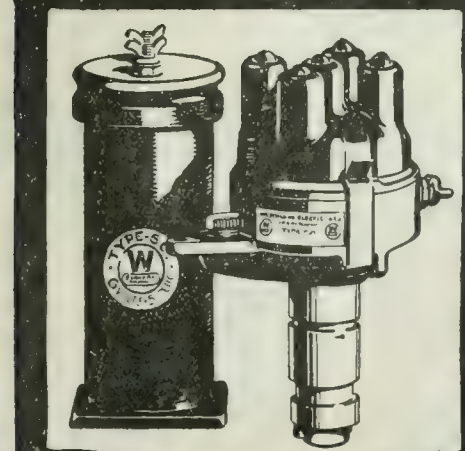
Westinghouse has provided for this by the employment of twelve Service Engineers who carry to the Branch Representatives not only expert technical assistance but the true spirit of Westinghouse Service as well.

The Car Builder who selects Westinghouse Starting, Lighting and Ignition Equipment for the car he manufactures can be sure that the purchasers of that car will be served by an organization that has the will to serve.

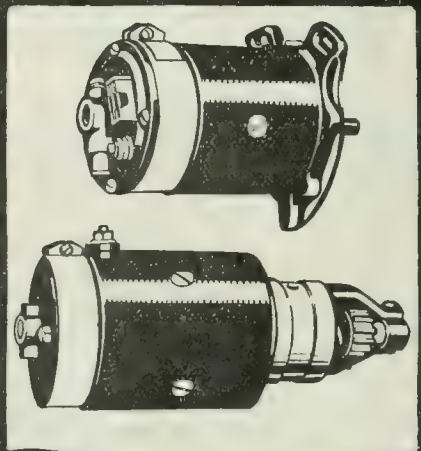
WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY
Automotive Equipment Department
Sales and Service Headquarters, 82 Worthington St., Springfield, Mass.

Service

Use only Genuine Parts.
Beware of Parasite Parts-Makers

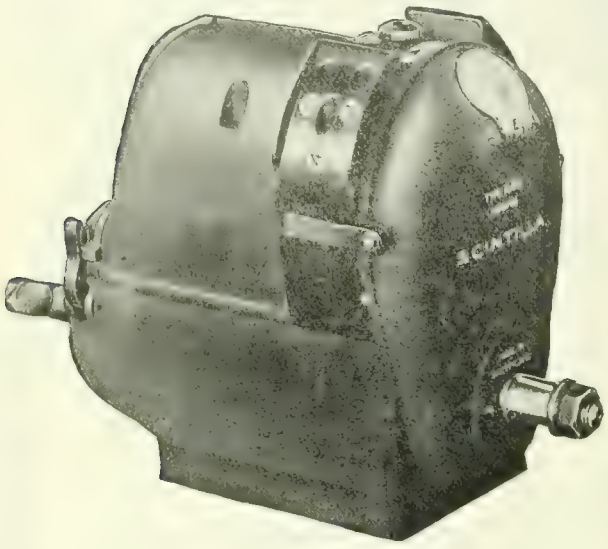


W
WESTINGHOUSE ELECTRIC



SCINTILLA

The Magneto with the rotating magnet and the stationary winding.



For 1 to 8 cylinder motors

THE Scintilla magneto could not be superior to other ignition systems if it were manufactured on a basis of price.

The superiority of Scintilla, which is made in Switzerland, is due to the fact that it delivers unfailing ignition.

Booklet sent on request.

SCINTILLA MAGNETO CO., INC.
225 WEST 57TH ST., NEW YORK

Positions & Men Available

The following announcements are published for the benefit of members of the Society and the convenience of companies in need of men. No charge whatever is made for this service. In the case of items prefixed by an asterisk further information is withheld at the request of the company or individual making the insertion, but written communications bearing the number of such items will be forwarded by the S. A. E. Office. In other cases further information will be supplied by the Office of the Society. Applications for positions from non-members must be endorsed by a member of the Society.

0154 GENERAL MANAGER for automobile body plant desires position. Experience includes 20 years as mechanic, engineer and superintendent and factory, business and sales management. Competent to produce open or closed work from raw material to the finished product, including paint, trim and final assembly. Available at once.

0193 MECHANICAL ENGINEER with industrial and executive experience who is familiar with modern methods of manufacturing, production and organization wishes responsible work with a progressive organization. Eastern States or foreign service preferred. Age, 31; married.

0250 ENGINEER Keen, energetic, experienced and reliable man with 14 years' practical experience in automobile and aircraft lines covering various executive positions in designing, development and experimental work desires to make a permanent connection with a reliable organization where ability, energy and initiative are wanted. Has been associated with the leading engineers and largest manufacturers in the country. Can serve as a commercial representative, experimental manager, chief engineer or assistant. Will go anywhere. Age, 31; married. Excellent references can be furnished.

0255 EXECUTIVE AND DESIGNING ENGINEER experienced in tracklaying tractor and transmission design, factory planning, power transmission and conveying machinery desires responsible position with truck, tractor, or parts manufacturer. Age, 37; unmarried. Available at once.

0256 PRACTICAL ENGINEER with 12 years' experience in experimental testing and laboratory work and 8 years in service repairs. Expert on internal-combustion engines. Available at once. No preference as to location. Age, 36; married.

0257 AUTOMOTIVE ENGINEER with 9 years' experience in the design and production of automobiles, trucks, tractors and airplane engines, specializing in internal-combustion engine design and construction. Capable of organizing and supervising engineering department. Good references. Location immaterial. Age, 29; married.

0258 YOUNG MAN with five years' experience in the design, layout and construction of automotive parts, crude oil engines, motor cultivators and garden tractors, wishes to change position. Available now. Age, 24; single. Location, immaterial.

0259 ENGINEER Nine years' experience in electrical, testing and finished inspection and experimental laboratory departments. For past year in complete charge of research laboratory and garage.

0260 GRADUATE MECHANICAL ENGINEER with 13 years' experience in tool engineering and factory management, desires a position as chief tool designer or assistant factory manager. Location, Detroit preferred, but not essential.

(*Continued on page* 46)

Quality: the Most Value Per Dollar!

The Willard Threaded Rubber Battery is built for the buyer who recognizes the truth of the principle that a few dollars added in cost can be made to return many dollars of extra value.

Every detail of material and construction has to measure up to the rigid Willard standards of excellence. But over and above this general high quality of product is this important factor—Threaded Rubber Insulation—the most important battery invention in years.

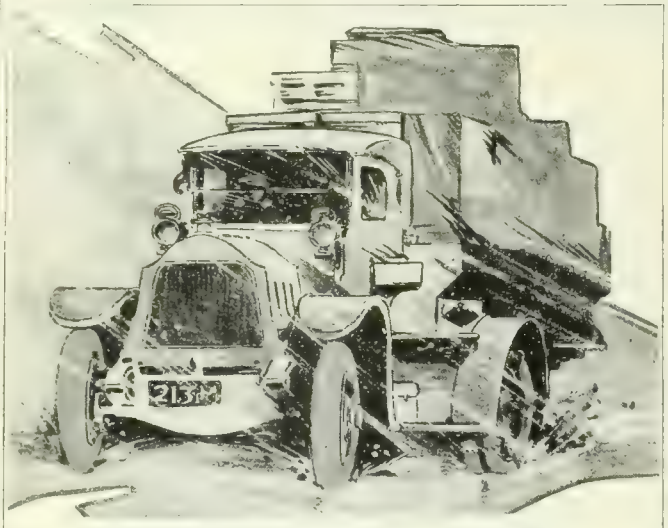
Threaded Rubber Insulation puts an end to annoying reinsulation bills and gives the car owner a feeling of security he cannot get in any other way; it lasts the life of the battery plates.

Threaded Rubber Insulation is found in only one battery—the Willard Threaded Rubber Battery—the one selected by the builders of 188 makes of cars and trucks. Discriminating battery buyers have learned to recognize it by the Thread-Rubber Trade Mark, stamped in red on the side of the battery case.

WILLARD STORAGE BATTERY COMPANY
Cleveland, Ohio

Made in Canada by the
Willard Storage Battery Company of Canada, Limited, Toronto, Ontario

Willard THREADED RUBBER BATTERY



FIGURING ON TRACTION'S PEAK

YOUR STATISTICS show that based on performance records your trucks should be built not for three, five, or ten ton loads on level, smooth highways, but for the peak strain of up-hill, down-dale traction through heavy mud and ice.

AT LEAST ONE company has advanced beyond this and is now building trucks of a specified size, not naming the capacity. Their engineers seem to have realized that traction over ice and mud is an unusually heavy drain on the truck's power plant, and is so different from ordinary going that a truck cannot be fairly rated on either this or level-road traction.

PUTTING THE POWER back in rear wheels to keep them from whirling on ice or becoming stuck in deep mud—is easily accomplished by quickly attached ARROW GRIPS.

ARROW GRIPS have but two parts—a clamp and chain. The clamps are made from malleable iron and rust-proofed by special process. As they do not injure the spoke, they can remain there indefinitely. The chains are built of especially welded steel and will stand tremendous pressure.

Correspondence is invited relating to the attractive features of ARROW GRIPS as standard equipment.

ARROW GRIP MFG. CO., Inc.
GLENS FALLS, N. Y.

Export Office: 280 Broadway, New York

ARROW GRIP
NON-SKID CHAINS FOR SOLID TIRE VEHICLES

Reg. U. S. Pat. Off.

MEN AVAILABLE
Continued

0261 ENGINEER experienced in production, inspection and research, desires a position in Michigan, Indiana or Wisconsin, but would consider other location. Available after one month's notice. Married; age, 34.

0262 ENGINEER will consider position as department foreman, superintendent of small plant or traveling salesman. Has had 16 years' experience in nearly every phase of the automobile industry and for past 9 years has been manager of prominent manufacturing company.

0264 ENGINEER Technical graduate, lately in Government service as automotive engineer in Ordnance Department; shop organizer, production manager and general superintendent of largest Government shop in the East, wishes to make connection with reliable firm, representing them in Western territory in either manufacture or sales. Best of references furnished. California headquarters preferred. Age 35.

0266 TECHNICAL GRADUATE desires to secure a position as plant or automotive engineer. Twelve years' experience. At present chief engineer of well-known company building high-grade automobiles.

0269 ENGINEER Ten years' experience in the design and manufacture of automotive parts, transmissions a specialty. Married; age, 28.

0271 ENGINEER and designer of trucks, tractors and passenger cars desires a position. Age, 30; unmarried. Available at once.

0272 PURCHASING AGENT who is familiar with all phases of the automotive industry, and is also a practical engineer, desires position. Unmarried; age, 30. Available at once.

0275 YOUNG ENGINEER Experienced in aircraft design, production, construction, development, inspection and experimental work. Technical graduate. Age, 26; unmarried. Location, immaterial. Available now.

0276 AUTOMOTIVE ENGINEER University graduate with four years' experience in the layout and design of leading automobile truck and tractor, who has done considerable research and design work on gears, wishes to connect with a progressive company. Has had some sales experience and can furnish excellent references.

0278 CHIEF INSPECTOR who has had 12 years' experience on passenger cars and trucks. Has been associated with large automobile company for past three years exercising complete supervision of the entire plant including both the incoming material and the finished product.

0279 YOUNG MARRIED MAN desires permanent position in either the engineering or the service department with a company building passenger cars in or near Chicago, Cleveland or on the Pacific coast. Available on 10 days' notice.

0280 CHIEF ENGINEER or factory manager with 15 years' experience is available at once for permanent or temporary position. Has an established reputation and professional standing in the automotive industry.

0281 HIGH-GRADE EXECUTIVE with 15 years' experience in management and sales engineering in the truck, tractor and engine organizations is desirous of connecting with a manufacturer where opportunities are big. An expert in organizing, planning and management. Age, 35; married. Available at once. No preference as to location.

0283 AUTOMOTIVE ENGINEER experienced in development and design desires to make a permanent connection with a motor-truck or passenger-car builder. Age, 34; married. Available on reasonable notice. East preferred.

0285 ENGINEER who has developed a successful steam car built with 90 per cent of standard automobile parts is available for position. Has now finished the design and detail drawings, his own property, and wishes to meet party interested in building a finished car on an equitable basis.

(*Continued on page* 48)

See announcement at the head of the "Positions and Men Available" column, page 44.

AUTOMOTIVE ELECTRICAL EQUIPMENT

Built to S. A. E. Standards

NORTH EAST ELECTRIC CO.

ROCHESTER, N. Y., U. S. A.

Manufacturers of

STARTER-GENERATORS
GENERATORS
STARTING MOTORS
IGNITION SETS
IGNITION GENERATORS
ELECTRIC HORNS

SERVICE FOR NORTH EAST EQUIPMENT OFFICIALLY HANDLED BY

NORTH EAST SERVICE INC.

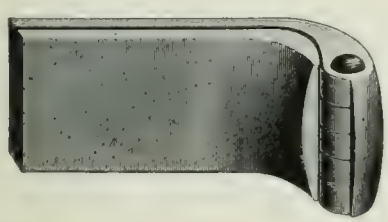
Rochester, N. Y., U. S. A.

Atlanta, Ga.
Chicago, Ill.
Detroit, Mich.
Kansas City, Mo.
New York

Rochester, N. Y.
San Francisco, Cal.
Windsor, Ont., Can.
London, Eng.
Paris, France

E

VEHICLE HARDWARE

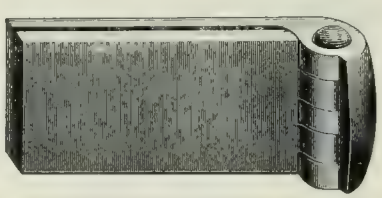


No. 9503

Lamp Brackets

Hinges

Hood Fasteners



No. 9507

MALLEABLE IRON CASTINGS

THE EBERHARD MANUFACTURING CO.

CLEVELAND, OHIO

SPRINGS

THE WM. D. GIBSON CO.

1800 CLYBOURN AVE.

CHICAGO

We are equipped to make any kind or size of springs except elliptics, and we have fifty years of experience combined with every up-to-date scientific appliance for heat treatment. We specialize in high grade springs of carbon or alloy steels for valves, clutches and other exacting requirements.

Send for our Treatise on Springs.

MARKO STORAGE BATTERIES

WILL HELP YOU TO ATTAIN

LOWER COSTS

MARKO STORAGE BATTERIES

are quality built by an organization with 14 years of battery experience. They contain more practical features than any other storage battery in the field. Further particulars will gladly be furnished, if interested.

Built in
S. A. E. STANDARD SIZES

PAUL M. MARKO & CO.
1402-1412 Atlantic Avenue
BROOKLYN, N. Y.

MEN AVAILABLE
Continued

0286 MECHANICAL AND ELECTRICAL ENGINEER Technical graduate with 12 years' experience, a specialist on oil engines and capable of taking charge of the design and construction of high-speed oil engines, truck axles, jigs and tools, desires a position with a progressive company. Best of references. Age, 35; married.

0287 ELECTRICAL ENGINEER Graduate in electrical engineering with 12 years' experience in research and development work on motor control for general motor applications, including traction, electric automobiles and trucks. Age, 33; married.

0288 MECHANICAL ENGINEER competent to act as works or production manager, chief engineer or assistant to executive, desires a position where initiative and inventive ability along manufacturing lines are considered. Experience includes 12 years as machinist, designer, chief draftsman and efficiency and production engineer. Wide experience in designing special machinery, tools, jigs, fixtures, gages and dies. Has been engaged for the past three years in airplane design and construction and is familiar with the use of duralumin. Capable of handling men and supervising responsible work. Can speak French and Italian. Will go anywhere in the United States and will consider South American or European work. Best of references. Available on short notice.

0289 YOUNG ENGINEER with two years' experience in experimental and shop work desires a position in the engineering department of a progressive company. College graduate. Age, 26. Willing to go anywhere.

0290 MECHANICAL ENGINEER desires position. Has had seven years' experience as metallurgist and testing engineer for plants manufacturing automotive products. Experience also includes selling and public utility work. Married; age, 30. Available at once. Middle Atlantic States preferred but not essential.

0291 MECHANICAL DRAFTSMAN AND TOOL DESIGNER with eight years' experience on automobile transmissions, clutches, universal-joints, tractors and the tools, jigs and fixtures required in their production, desires a position with a progressive automotive company in these lines or to take charge of assembling or testing. Location, Detroit or Middle West. Age, 28; married. Available at once.

0292 MECHANICAL ENGINEER Ten years' experience in design, experimental work and production. Technical graduate. Has held the positions of assistant, chief and consulting engineer. Available immediately. Age, 34; married.

0293 AUTOMOTIVE SALES ENGINEER is open for engagement. Has had both foreign and domestic experience.

0296 AUTOMOTIVE ENGINEER Technical graduate with 12 years' experience in the development and construction of high-price passenger cars and trucks and for the last few years chief experimental engineer with one of the largest companies in the country. Best of references.

0297 METALLURGIST with technical education, executive ability and over six years' experience in general laboratory and heat-treating practice, desires to make connection with a progressive manufacturer. At present holds a responsible position with a prominent organization. Will consider any location, but Pacific coast preferred. Age, 29.

0301 SALES ENGINEER College graduate with eight years' experience as a sales engineer and four in the automotive trade desires a position with a reliable accessory manufacturer. Age, 32; married. Location, immaterial. Available at once.

0302 DESIGNER Experienced in the design and inspection on up-todate metal or wood airplanes. Has held an executive position on airplane design and construction. Possesses a broad knowledge of all high-speed motor vehicles. Best of references and record of personal achievements furnished. Prefer Middle West territory, but would consider any other locality. Married; age, 34.

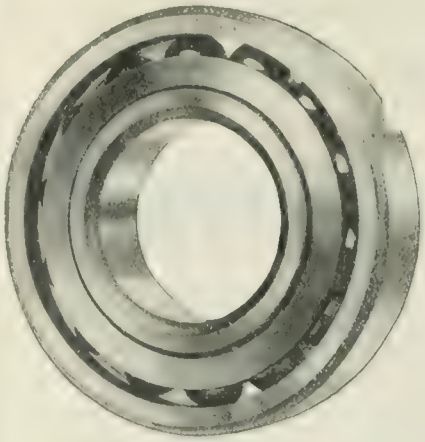
(*Continued on page* 50)

See announcement at the head of the "Positions and Men Available" column, page 44.

Accuratime
INTEGRAL CAM SHAFTS

Built By
MUSKEGON MOTOR SPECIALTIES COMPANY
MUSKEGON, MICHIGAN.

By Reputation—"The Best Cam Shafts Made"



Speed

YOU don't have to use ball bearings to keep things turning. This old world has been jogging along for quite a number of years, and until recently without ball bearings. There are other kinds that work passably well. We have seen old water wheels running fine with cast iron gudgeons running in sandstone boxes.

But things are speeding up a bit now. Spindles and shafts have to run now at speeds that a few years ago were utterly impossible. Twenty-five, forty, and even fifty thousand revolutions per minute are not only possible but are practical every day facts. The thing that made this possible is the modern ball bearing. And the particular ball bearings that are doing it are GURNEY'S

Gurney Ball Bearing Co.
Conrad Patent Licensee
Jamestown, N. Y.

GURNEY
BALL BEARINGS
18102

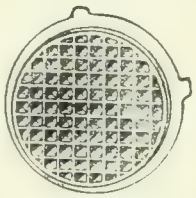
DOEHLER
DIE-CASTING CO.
WORLD'S LARGEST PRODUCERS OF
DIE-CASTINGS
TIN-LEAD-ZINC-ALUMINUM-ALLOYS.
DO-DI BRASS.
MAIN OFFICE AND EASTERN PLANT
BROOKLYN N.Y.
COURT, 9TH AND HUNTINGTON STS.
CENTRAL PLANT
TOLEDO O.
SMEAD & PROSPECT AVES.
WESTERN PLANT
CHICAGO ILL.
COTTAGE GROVE AVE. & 91ST ST.

THESE ARE DAYS OF COMPETITION

WHAT may seem to you a trivial refinement may be a deciding factor in many sales in these times. Your dealers need every minute feature that will make the car more attractive to the buyer.

PERFECTION RUBBER PEDAL PADS

Are one of these *little* refinements which make a *big* impression. They look well and eliminate foot slipping. Your letter request brings a trial set.



AUTO PEDAL PAD COMPANY
318 West 52nd Street
New York City

ANDERSON AUTOMOBILE SPRING LUBRICATOR

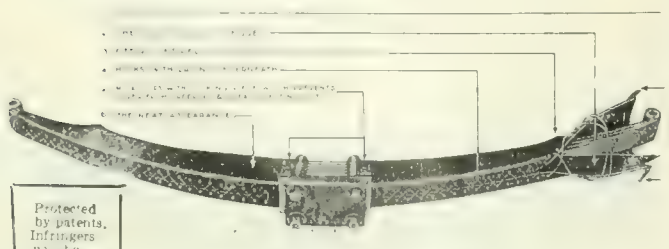
Reg. U. S. Pat. Office

For Winter Driving

Keeps springs working smoothly during the strenuous days of snowy weather. Rust-creating slush and icy water are kept out—grease is kept in. Assures flexibility of spring action, practical insurance against spring breakage from frozen ruts. Easily attached, no further attention needed. In real or artificial leather for all makes of cars and trucks. State make, year, model, type and number of passengers when ordering.

Anderson Spring Lubricator Co., Inc.
44 Lansdowne St. Boston, Mass.

Anderson Lubricators are being attached as standard equipment by distributors of several fine-grade cars. Write us for full details.



Protected by patents. Infringers will be prosecuted

"Spats for Springs"
Reg. U. S. Pat. Office

MEN AVAILABLE
Continued

0303 DESIGNER with several years' experience wishes to connect with manufacturer of cars or bodies or parts as chief draftsman. Experienced in handling men and correspondence and installing systems. Age, 27; unmarried. Available immediately.

0304 MECHANICAL ENGINEER Technical graduate with seven years' broad engineering and executive experience in the automotive industries covering rubber products, aeronautics, motor cars and trucks. Will go anywhere, but would prefer Middle West.

0305 AUTOMOTIVE ENGINEER with eight years' experience in automobile, truck, tractor and power farming machinery; also tool design and drafting who has held the positions of chief draftsman, factory superintendent and assistant chief engineer desires a position in the engineering or the service department of an automobile, truck or tractor firm. Middle Western location preferred, but not essential. Age, 24; unmarried.

0306 MECHANICAL AND ELECTRICAL ENGINEER Technical graduate and factory executive with long and varied experience in the design and manufacture of high-class accurate machinery wishes to connect with a firm where he can prove what he is able to do. Is especially well qualified in special tooling and manufacturing methods and has handled practically every department in manufacturing plant. Available now. Married; age, 47. Location immaterial.

0307 ENGINEERING MANAGER OR CHIEF ENGINEER Position wanted by engineer of technical and business experience who has been connected with one of the financially successful motor-car companies as chief engineer for 10 years and has specialized in the complete cooperation between manufacturing and finance departments to secure commercial success.

0308 PRODUCTION AND INSPECTION EXECUTIVE Man with practical experience of twenty years in the automobile and truck business wishes a position with a reliable company where merit is recognized with promotion. Age, 47; married. Available ten days after notice. Location immaterial.

0309 AUTOMOTIVE AND ELECTRICAL INSTRUCTOR Practical man with ten years' mechanical experience, including two years as senior instructor. Married; age, 27. Available at once.

0310 AUTOMOTIVE ENGINEER 33 years of age with an excellent record in the design, testing and development of particularly difficult problems of special improvements and accessories for the automobile powerplant and chassis desires to connect with firm requiring a specialized development engineer who has ingenuity, progressive ideas and a practical knowledge of this line of work. Available, Jan. 1. Single. Prefers New York City but would consider other location.

0311 ENGINEER Long experience in production, sales work, truck manufacturing and distribution. Has held positions of general manager and executive and has spent some time abroad with a tractor to be used in reclamation work. Age, 49; married. New York City preferred but not essential. Available immediately.

0312 YOUNG MECHANICAL ENGINEER desires a position in development or production work. Nine years' similar experience with organizations building airplane and stationary engines, airplanes and small tractors. Capable worker accustomed to responsibility. First-class references. Available now. Single; age, 27. Boston preferred but not essential.

0313 ENGINEER AND EXECUTIVE who has spent seventeen years with prominent automobile manufacturers on designs and production and in executive capacities seeks new connections. Has designed and produced complete automobiles and trucks, including engines, transmissions and axles, and recently completed models of new passenger car possessing many distinctive features and of unusually light-weight construction. Several years' executive responsibility. Is thoroughly conversant with latest production methods. If desired can furnish a competent organization. Married; age, 37. Location immaterial.

(*Continued on page* 52)

See announcement at the head of the "Positions and Men Available" column, page 44.

Muncie Wood Wheels

"Quality First"

Our advanced factory equipment and thorough knowledge of wood wheel building enable us to make an *All Hickory Wood Wheel* that we know will meet your every requirement under all conditions of road or load.

All work from the standing tree to the finished wheel is done in our own mill and factory.

Let's get together and talk it over.

MUNCIE WHEEL COMPANY, Muncie, Indiana

WE SOLVE MA VIBRATION PROBLEMS

Trade Mark Registered

Vibrations

Caused by Lack of Balance
DESERVE YOUR CLOSEST ATTENTION

DO YOU CONSIDER THEM IMPORTANT?

WHEN vibrations caused by unbalance of crankshaft and flywheel CAN BE ELIMINATED so surely and so economically, is it good policy to permit the annoyance of "engine periods" to lessen the public's esteem of your car?

Let us tell you what other automotive engineers have found it possible to do with an MA **Balancing Machine.**

See the machine actually balancing crankshafts at New York and Chicago Auto Shows.

The fact that not one MA **Balancing Machine** has ever been discarded, or its use discontinued, indicates its value.

How About Torsional Vibrations?

VIBRATION SPECIALTY COMPANY

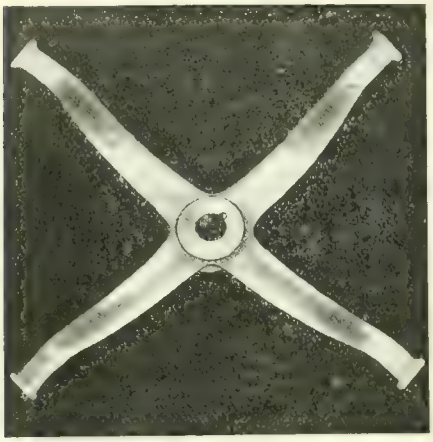
N. W. AKIMOFF, President

HARRISON BUILDING **PHILADELPHIA, U. S. A.**

SOSS

DIE CASTINGS

TIN, LEAD, ZINC, ALUMINUM ALLOYS



Steering Wheel Spider of Aluminum Alloy

Submit Your Die Casting Problems to Us

SOSS MANUFACTURING CO.

Grand Ave. and Bergen St. Brooklyn, N. Y.

Wilful Destruction

Your tires are being just as wilfully destroyed when you run them without proper air pressure. The axe process may be faster, but under inflation is just as deadly.

Don't guess at tire inflation.

Adopt the one SURE method

Use a

SCHRADER UNIVERSAL TIRE PRESSURE GAUGE

and know that your tires are properly inflated.

Invest $1.25 to-day and watch your investment pay dividends in tire mileage.

At all dealers everywhere.

A. SCHRADER'S SON, INC.

BROOKLYN, N. Y.

CHICAGO TORONTO LONDON

POSITIONS & MEN AVAILABLE
Continued

0314 TECHNICAL GRADUATE desires a position as metallurgist or superintendent of heat-treating. Six years' extensive experience in the chemical and physical testing and heat-treatment of carbon and alloy-steels. Best of references. Age, 31; married. Available after two weeks' notice. New York or New Jersey preferred but not essential.

0320 EXECUTIVE Successful organizer as manager, general superintendent and engineer with 14 years' experience in handling men mostly in the construction of marine and automobile engines. Has had practical as well as technical training in the shop and the foundry. Age, 39; married. Prefer Cleveland or vicinity. Available at once.

0321 MECHANICAL ENGINEER Experience includes 16 years as chief draftsman and designer, also broad experience in the designing of special machinery, tools and dies. Age, 41; married. Available on one week's notice. Location immaterial.

0325 COMMERCIAL BODY ENGINEER AND DESIGNER Man with a good record who has experience in modern commercial body design including cabs and windshields and standard and special platform and stake, express and panel bodies and is capable of managing a body shop wishes to connect with a firm where there is an opportunity for advancement. Has made a particular study of bus bodies. Available on two months' notice. Age, 28; married. Location immaterial.

0326 ASSISTANT FACTORY MANAGER Technical graduate and competent executive with 12 years' practical experience as assistant production manager, superintendent, machinist and tool maker. Is familiar with factory organization and production methods for quality and quantity production and has an appreciation of costs in general and especially factory costs in various industries through work as a consulting engineer. Detroit preferred.

0327 AUTOMOTIVE ENGINEER with sixteen years' experience who has built a truck engine in a way to economize upkeep is available for position where he can be of service along this line.

0328 ENGINEER Fifteen years' automobile engineering, designing and supervision experience and for the past five years assistant engineer of prominent automobile company. Available immediately.

0329 ENGINEER with an exceptional practical mechanical experience including experimental improvement and general development work and production, purchases and design. Is capable of taking the entire charge of the engineering department of a small or medium-sized passenger-car, truck or engine factory, preferably the last. Possesses a thorough knowledge, both theoretical and practical, of internal-combustion engineering. Has held the position of chief engineer and has built, developed and exploited a semi-sleeve valve engine. Age, 37; married.

0331 EXECUTIVE MECHANICAL ENGINEER Man who has specialized in automobile and tractor engine transmission and rear-axle design and also automatic production and general machine design. Experienced in purchasing and general executive requirements of large and small organizations. Age, 35; married. Available now.

POSITIONS

111 INSTRUCTOR Man with a thorough knowledge of automotive electrical equipment. Must be young and possess ability to handle young men. An ex-service man would fit in well if he had the necessary qualifications

116 SALESMEN who have initiative, strong personality and who have been in direct contact with the buying public are desired to sell passenger cars on a commission basis.

(*Continued on page* 54)

See announcement at the head of the "Positions and Men Available" column, page 44.

Interstate Alloy Steels

ARTIST VERNON HOWE BAILEY, when he sketched the picture below, caught the spirit and the tense action of the hundreds of workers in the Interstate Billet Chipping department, at our South Chicago Works. But the readers of this publication will see more in this picture than even that world-famous artist saw.

Your practical mind will grasp, as we do, the importance of removing the smallest defect in every alloy steel Billet before it is heated for rolling into bars. You are familiar with the behavior of alloy steel (especially the nickel group) in the rough-rolling process which reduces ingots to billets, and have seen the surface creases and seams in the cooled billets. And you can imagine the cost to us of pickling, inspecting and chipping every individual billet.

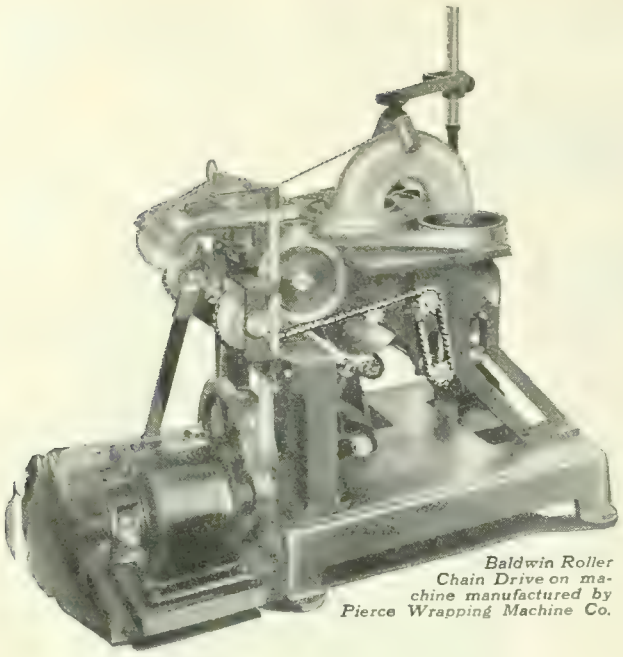
Our care in this department and our slow method of rolling the reheated billets—many passes, with a small reduction at each pass—coupled with our advanced pack-annealing practice, insures finished bars or spring steel of a uniformly dependable high quality.

We supply all S A E specifications as well as many special analyses of our own; and we are skilled and patient in working out customers' analyses as well.

Interstate Iron and Steel Co.

104 South Michigan Avenue, Chicago

Branch Offices—New York, Cleveland, Detroit, Milwaukee, St. Paul, St. Louis, Kansas City, San Francisco



Baldwin Roller Chain Drive on machine manufactured by Pierce Wrapping Machine Co.

ONE fine thing about the Baldwin Chain Drive is its adaptability—its ability to fit and function well where other drives cannot. This Baldwin Chain Drive on the Pierce Wrapping machine is a typical example of this quality.

BALDWIN DISTRIBUTORS

Boston, Mass.	Walter H. Williams, 175 Massachusetts Ave.
Buffalo, N. Y.	Baldwin Service Co., 262 Oak St.
Chicago, Ill.	W. D. Foreman, 22 E. 18th St.
Cincinnati, Ohio	Wirthlin-Mann Co., N. E. corner Plum & Commerce Sts.
Cleveland, Ohio	Chain & Sprocket Service Co., 1794 East 55th St.
Dallas, Texas	Geo. J. Fix, 209 N. St. Paul St.
Detroit, Mich.	Baldwin Service Co., 8341 Woodward Ave.
Kansas City, Mo.	Motor & Machinists Supply Co., 1617 Grand Ave.
Kansas City, Mo.	The Faeth Company, 1117-1131 W. Eighth St.
Los Angeles, Calif.	Colyear Motor Sales Co., 1222-1228 South Hill St.
Minneapolis, Minn.	Baldwin Service Co., 1020 LaSalle Ave.
New Orleans, La.	M. H. Rykoski, 706-708 Julia St.
New York City	C. D. Schmidt Co., 276 Canal St.
Philadelphia, Pa.	N. A. Petry Co., Inc., 328-334 North Randolph St.
Pittsburgh, Pa.	Baldwin Service Co., 100-108 Liberty Ave.
Portland, Oregon	H. W. Sharp Co., 68-70 First Street.
Providence, R. I.	Lanphear Motor Car Co., 17 Snow St.
Salt Lake City, Utah	W. C. Van Horbek, 433 South Main St.
San Francisco, Calif.	The Adam-Hill Co., 96 Ninth St.
Seattle, Wash.	Wade & Co., 1423 Twelfth Ave.
St. Paul, Minn.	C. J. Smith Co., 155 W. Fifth St.
Spokane, Wash.	Baldwin Sales & Service, 620 W. Second St.
St. Louis, Mo.	Ferrier Automotive Equipment Co., 3200 Locust St.
Montreal, Toronto, Winnipeg, Can.	Lyman Tube & Supply Co., Limited.

BALDWIN CHAIN & MFG. CO.
WORCESTER, MASS.

H. V. GREENWOOD, *Western Sales Representative*
PEOPLES GAS BUILDING, CHICAGO, ILLINOIS

GENUINE BALDWIN CHAINS

POSITIONS AVAILABLE
Continued

127 SALESMAN who is in close touch with automotive engineers is desired, to introduce to the industry several laboratory devices including a high-speed balanced diaphragm type indicator.

135 RESEARCH ENGINEER to take charge of lubrication department of Government laboratory at Washington.

140 SALES ENGINEER Manufacturer of electrical equipment requires traveling sales engineer to sell product to manufacturers of high-grade automobiles and gasoline engines. Unusual opportunity for first-class man having broad selling experience.

146 ENGINEER who is experienced in ignition work. Drafting experience essential. Good opportunity for advancement. Location Pennsylvania.

151 CITY SALESMAN to call upon repair shops, garages and large users of motor trucks and sell them magnetos. Location, New York City.

160 SALES MANAGER who is familiar with the sale of gears and gear cutting machinery. Location, Indiana.

164 SALES ENGINEER ON CARBURETERS Preferably a man with technical experience and acquaintance among the large automobile manufacturers. Must be of highest character and have initiative to work up a new proposition. Returns will be commensurate with results achieved. Location, Wisconsin.

174 RESEARCH ENGINEER, for work on starting and lighting. Man with experience along this line and who can take charge of the work immediately. Location, Boston.

175 SALES ENGINEERS Location, Ohio.

179 TRANSPORTATION SALES ENGINEER to represent Southern company in New England and New York on commission basis, selling trailers and motor-truck equipment.

181 SALESMAN with some experience in ignition, or at least in some part of automobile work. A high-grade man who can get business for the company is wanted. Location, Pennsylvania.

182 SALES MANAGER for a large motor-truck company located in Ohio. Must be a man of wide experience and capable of handling a large number of men in the field.

*183 DESIGNER OR DRAFTSMAN who is capable of handling ball-bearing layouts and applications and making recommendations as to sizes. Must have had a considerable amount of actual experience in this work. Excellent opportunity for high-grade man. Location, Pennsylvania.

188 SALESMAN Man with successful experience in selling automobiles at wholesale is wanted by Philadelphia firm.

190 SALESMAN for passenger cars. Location, New York City.

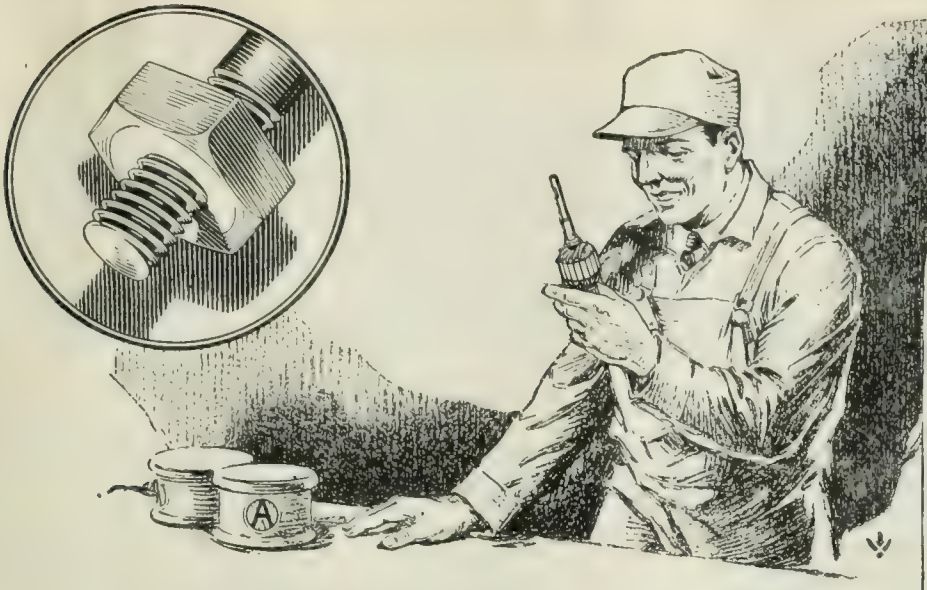
192 DRAFTSMAN Temporary position with motor-vehicle company. Location, New York State.

193 PRODUCTION MAN Wanted an experienced and practical man. He must have the highest credentials and at least 10 years' experience building medium-priced cars. A permanent position for the right person. Correspondence confidential. Location, Florida.

*194 SALES MANAGER is wanted by a well-known automobile organization selling a medium priced individual type of car. A man capable of enlarging and developing the present dis-

(*Concluded on page* 56)

See announcement at the head of the "Positions and Men Available" column, page 44.



"This wire fits like a nut on a bolt"

"It's right! *It goes in the space.* That's why I'm doing better work."

Acme Wire accounted for the sudden increase in this winder's production, and, what is more important, fewer rejections and better wound coils throughout. That was because Acme Wire is uniform, free from lumps and imperfections, speedy in winding, and really "*goes in the space.*"

Such instances are common; in fact, usual, when Acme Wire is used rather than inferior wire—bought on a price basis. For Acme Wire is made carefully—every step in the process is based on standards of performance in the buyer's winding room. From the very start of the Acme enterprise their strict adherence to quality standards has been notable in the industry.

Acme Wire—*it goes in the space.* There's magic in those words for the operator who no longer has to stop work to cut out poor wire, for the engineer who wants his specifications filled exactly, so that his coil can be built as he designed it, and for the Purchasing Agent who keeps in close touch with the Winding Room and knows that cheap wire does not always mean inexpensive coils.

Illustrated Catalog on Request to Engineers, Purchasing Agents, Executives and Operators.

THE ACME WIRE CO., New Haven, Conn.
NEW YORK CLEVELAND CHICAGO

Some Users of Acme Magnet Wire

Air-Way Electric Appliance Corporation
Bijur Motor Appliance Co.
Century Electric Co.
Crocker-Wheeler Co.
Cutler-Hammer Mfg. Co.
Dayton Engineering Laboratories Co.
Delco Light Co.
Domestic Electric Co.
Eisemann Magneto Corp.
Emerson Electric Mfg. Co.
Esterline-Angus Co.
Ford Motor Co.
General Electric Co.
Gray & Davis, Inc.
Holtzer Cabot Electric Co.
Hoover Suction Sweeper Co.
Klaxon Co.
Robbins & Myers Co.
Sangamo Electric Co.
Scovill Mfg. Co.
Simms Magneto Co.
Westinghouse E. & M. Co.
Willys Corporation (Auto Lite Division)

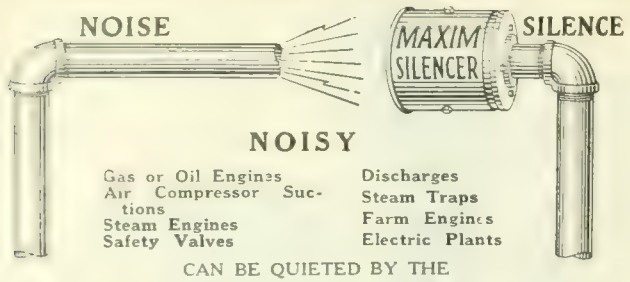
Acme Wire Products Include

"Enamelite," plain enameled Magnet Wire; "Cottonite," Cotton-covered "Enamelite"; "Silkenite," Silk-covered "Enamelite"; Single and Double Cotton Magnet Wire; Single and Double Silk Magnet Wire. We also have a complete organization for the winding of coils in large production quantities.

ACME

Acme Wire

"It goes in the space"



NOISY

Gas or Oil Engines
Air Compressor Suctions
Steam Engines
Safety Valves
Discharges
Steam Traps
Farm Engines
Electric Plants

CAN BE QUIETED BY THE

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Good Opportunity for DEALERS

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154 Ogden Ave. Jersey City, N.J.

Founded by a group of America's foremost industrial and technical experts who served on its Advisory Council.

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Among the thousands of unsuccessful inventions patented each year are many that possess real merit. They fail, however, because the inventor does not know how to develop and market them.

We are organized to furnish the inventor with business brains and technical talent of the highest calibre, asking in return only a fair share of the profits earned by the invention.

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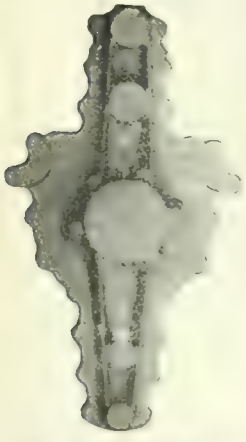

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Both at Syracuse, N.Y.

POSITIONS AVAILABLE
Concluded

tributors' organization, and who is thoroughly experienced in the selling end of the automotive industry is desired; preferably one who is now assistant sales manager, and who would be ready to step into the position of sales manager whenever the opportunity is offered. Location, Delaware.

*195 SECRETARY capable of handling own stenographic work is wanted by a prominent truck building company. Some mechanical knowledge and good personality essential. Good salary prospects for the right man. University graduate preferred. Location, New York City.

*196 MAN WITH IDEAS OR DESIGNS, patented or otherwise, of a light cheap horn is desired by a large manufacturing company intending to enter the automobile horn field.

198 LAMP SALESMAN. Must be thoroughly familiar with automobile lamps, acquainted with the trade and qualified as to mechanical knowledge. A previous successful record in this line is essential. Give experience in detail and personal description. Location, Boston.

200 ENGINEER qualified to furnish a complete design of motorboat engines is wanted by Government. Preferably a man to develop these designs in the department so as to be able to have the advice and criticism of officers responsible for the design, but if this is not possible, designs could be prepared outside and submitted for criticism. Location, Washington.

201 ENGINEER to take full charge of an office and warehouse, carrying a well assorted stock of high-grade steel products such as tool, drill and high-speed steels, etc., is wanted for foreign service by a prominent steel company. Applicant must be an experienced steel salesman, practical, absolutely trustworthy, well recommended, thoroughly familiar with modern methods of heat-treating and qualified to act as a demonstrator. Man acquainted with the conditions peculiar to the Eastern markets preferred.

202 MAN thoroughly competent to handle the production design of automotive lamps. Must have had a number of years' actual experience in designing lamps for manufacture on a production basis. Location, Boston.

203 BODY DRAFTSMEN wanted by one of the established builders. Should be capable of making full-size body drafts and understand projection and all body framework and metal parts. Location, Detroit.

205 PACKAGE DELIVERY COMPANY commencing operations desires the services of an engineer who is thoroughly familiar with the cost of truck fleet operation and the unit cost of door-to-door delivery. Location, New York City.

207 BODY DESIGNER AND DRAFTSMAN Man to grow up in the business, preferably just out of college, is wanted. Experience not necessary. Location, suburb of New York City.

See announcement at the head of the "Positions and Men Available" column, page 44.

Raybestos MOLDED CLUTCH FACING
PATENTED ~ GUARANTEED

THE RAYBESTOS COMPANY

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Heavy Miscellaneous Stampings of all kinds

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Tapered Roller Bearings

have longer endurance, greater strength, and easier running qualities.

"They last longer Because they are stronger"

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WE offer our services to the engineering fraternity on layouts requiring Thrust Ball Bearings. Our broad engineering experience in Ball Bearings is at your disposal.

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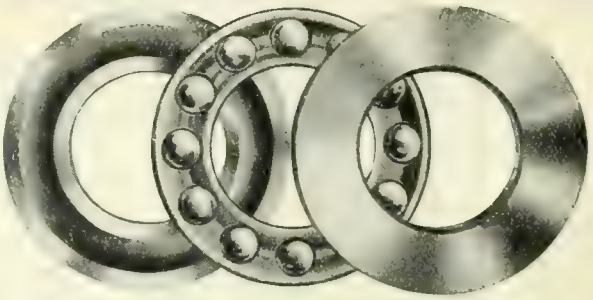

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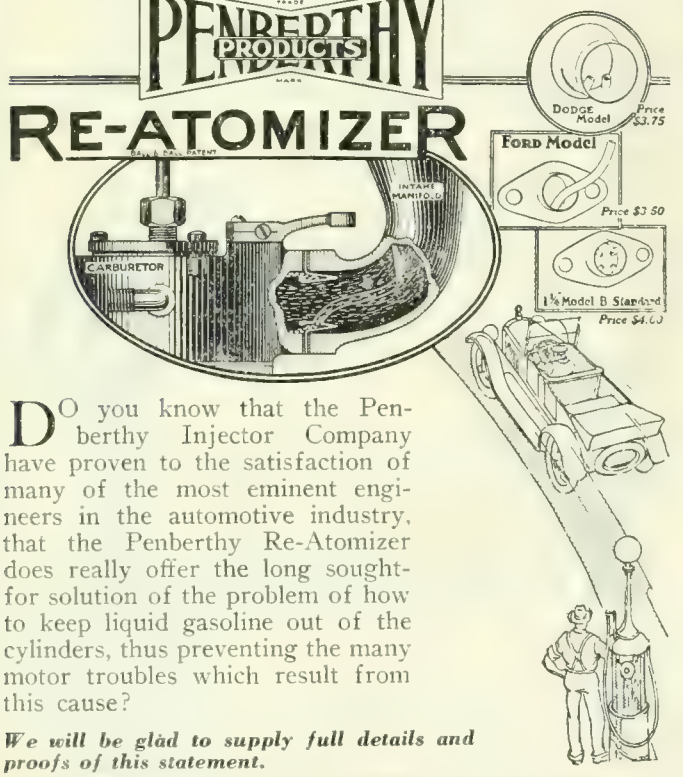

DO you know that the Penberthy Injector Company have proven to the satisfaction of many of the most eminent engineers in the automotive industry, that the Penberthy Re-Atomizer does really offer the long sought-for solution of the problem of how to keep liquid gasoline out of the cylinders, thus preventing the many motor troubles which result from this cause?

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Laminated Shims are made of thin layers of brass, which are peeled off to secure the thickness required for accurate bearing adjustments. Furnished babbitt-faced or plain. In standard patterns or to order.

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We are building axle housings, brake drums, and other parts for the heaviest motor trucks ever built, and have ample capacity for still heavier.

With our complete equipment we cover the entire sheet metal stamping line.

We solicit your inquiries.

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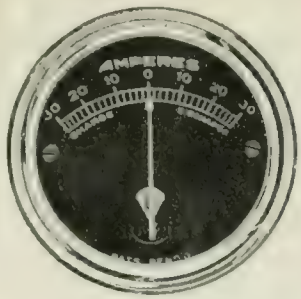
Watch  Your

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OWNERS of more than 2,500,000 motor cars equipped with Nagel ammeters are sure of instant, accurate warning of battery or generator trouble. They get this warning in time to prevent serious damage to these expensive car units or trouble and inconvenience to themselves. The dependability of the Nagel is the surest test of its fine quality.

The Nagel Ammeter is standard equipment on Austin, Auburn, Anderson, American, Beggs, Bell, Briscoe, Bour Davis, Chevrolet, Curtis, Collier, Handley Knight, Haynes, Luverne, Maxwell, Mitchell, Moore, Oakland, Oldsmobile, Jackson, Overland, Pan, Peugeot, Piedmont, Security, Stanwood, Stephens, Studebaker, The Southern Six, Vogue and Willys-Knight passenger cars, and Atlas, Collier, Commerce, Denby, Gramm Bernstein, Gorford, G. M. C., Kerns Dughie, Nash, Nelson, Olds, Republic and Stewart motor trucks. Also endorsed by use by the makers of the Auto Lite, Bijur, C. A. Vandervell (London, Eng.) and Remy Starting and Lighting Systems.

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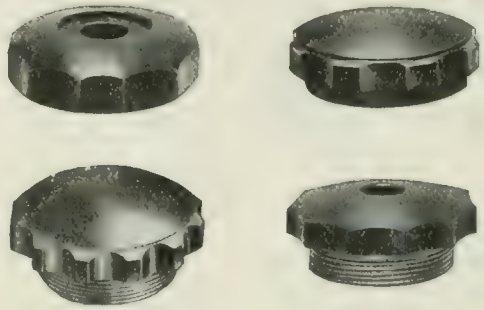

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Use Cold Molded Material to Reduce the Cost of Radiator Caps

Cold molding by the Aico process produces a Radiator Cap of the finest quality—lustrous, durable and heat resisting. Aico Radiator Caps are guaranteed not to warp, crack or change in color. They are not affected by anti-freeze mixtures.

In order that manufacturers of cars and trucks may better know the Aico process, we have established an engineering and designing department and placed it at their disposal. A request for additional information will receive the prompt attention of this department.

American Insulator Corp., New Freedom, Pa.

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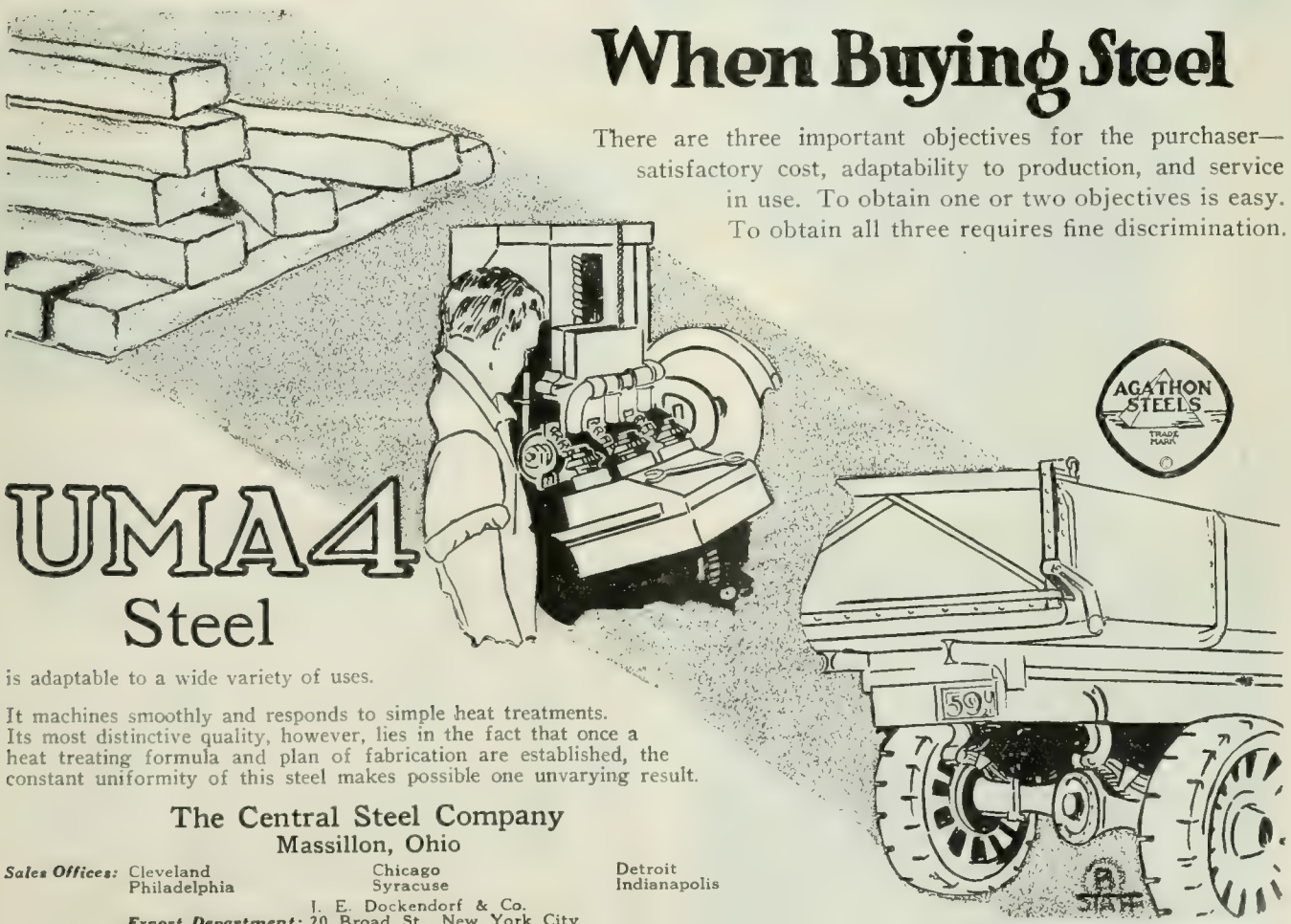

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There are three important objectives for the purchaser—satisfactory cost, adaptability to production, and service in use. To obtain one or two objectives is easy. To obtain all three requires fine discrimination.

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UMA4 Steel

is adaptable to a wide variety of uses.

It machines smoothly and responds to simple heat treatments. Its most distinctive quality, however, lies in the fact that once a heat treating formula and plan of fabrication are established, the constant uniformity of this steel makes possible one unvarying result.

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We can prove these statements on our first trial order.

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Effective July 1st, 1921, a 5% discount from Collision premiums on Commercial automobiles is permissible for the attachment of an approved front bumper and/or an approved radiator guard. (5% shall be the maximum reduction, even when both bumper and guard are attached.) This reduction shall apply to full coverage, $50 deductible, and $100 deductible.

This reduction in premium should make it worth your while to investigate the merits of the Mansfield Front Bumper, Standard and Packard Special Radiator Guards, all of which have been "Listed as Standard" by the Underwriters' Laboratories.

MANSFIELD STEEL CORPORATION

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CARTRIDGE CORES

The Strongest, Most Efficient Radiator

that can be made has a core built up of Cartridge Radiator Tubes. These tubes are *extruded* from pure copper blanks by a new process that gives unequalled uniformity and strength.

Such a radiator core is strong, rigid, and stays tight. No danger of corrosion. Easily repaired if damaged in accident. Can be built in any shape. Exceptional cooling capacity.

United States Cartridge Co., Lowell, Mass.

G&O Radiators

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Tubular and Honeycomb Radiators

NEW HAVEN CONN.

Industrial Depression?

And Yet—

One of Our Members increased his production in June 1921 more than one-third over that of June 1920.

When *you* need men to help you better your design, increase your production or boost your sales, let us put you in touch with some S. A. E. members who can do these things.

SOCIETY OF AUTOMOTIVE ENGINEERS EMPLOYMENT SERVICE

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See that your electrical apparatus is "NORMA" equipped

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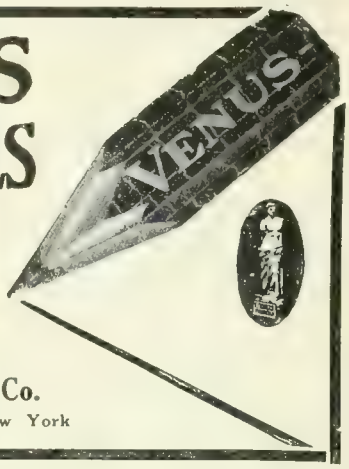

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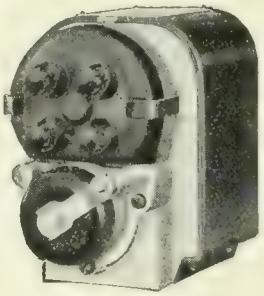

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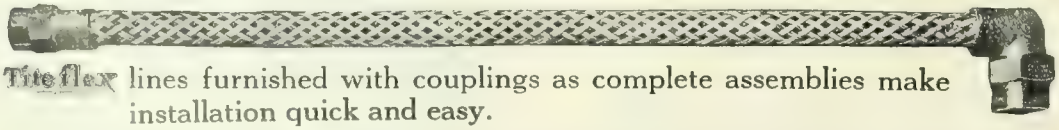

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*Light Mfg. & Foundry Co.
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*Bearings Co. of America
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*Bearings Co. of America
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Bearings, Bronze
American Bronze Corporation

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Central Steel Co.
Link-Belt Co.
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*Steel Products Co.

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Bolts, Spring Shackle
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Kerite Insulated Wire & Cable Co.
*Rome Wire Co.

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Clamps, Hose, C51
Schrader's Son, Inc., A.

Clamps, Machinists'
Eberhard Mfg. Co.
Williams, J. H., & Co.

(*Continued on page* 66)

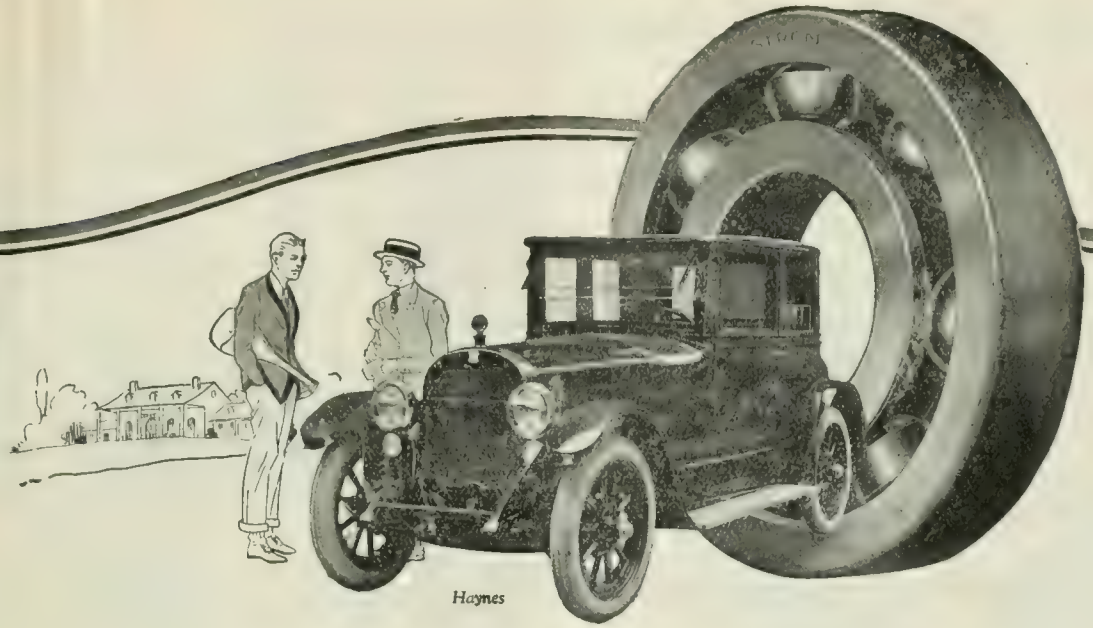
EXPLANATION OF SYMBOLS

Parts and Materials followed by key numbers have been standardized by the S. A. E. The numbers refer to S. A. E. HANDBOOK data sheets on which each standard is published.

*Companies whose names are preceded by an asterisk supply the parts or materials under which the company is listed as conforming with the S. A. E. Standard referred to.

**Parts and Materials followed by two asterisks indicate that two or more S. A. E. Standards are applicable. Information as to standards incorporated should be obtained from the manufacturer.

The addresses of companies listed in Sources of Supplies can be obtained from their current advertisements indexed on page 70.



STROM BEARING EQUIPPED

In the Haynes, America's first automobile, Strom bearings help maintain the strength, power and comfort for which this car of character always has been noted.

U. S. BALL BEARING MFG. COMPANY

Conrad Patent Licensee

4533 Palmer Street · CHICAGO, ILLINOIS

164

Strom BEARINGS

SOURCES OF SUPPLIES

Clutches, Engine, A1 and A2
*Brown-Lipe Gear Co.

Clutches, Power Transmission
Link-Belt Co.

Coils, Electrical Equipment
Acme Wire Co.

Conduit, Flexible, C52
*Titeflex Metal Hose Corporation

Connections, Tire-Pump
Schrader's Son, Inc., A.

Controls**
*Brown-Lipe Gear Co.

Cooling Systems**
*G & O Mfg. Co.
*Long Mfg. Co.
United States Cartridge Co.

Couplings, Flexible
Thermoid Rubber Co.

Covers, Axle-Housing
Sharon Pressed Steel Co.

Cranes, Portable Electric
Link-Belt Co.

Cranks, Starting, A13
*Steel Products Co.

Crankshafts
Canton Drop Forging & Mfg. Co.
Park Drop Forge Co.
Vibration Specialty Co.
Wyman-Gordon Co.

Cups, Oil and Grease, C57
*Bowen Products Corporation

Cutters, Milling
Haynes Stellite Co.

Cutters, Woodruff
Whitney Mfg. Co.

Dampers, Vibration
Vibration Specialty Co.

Dashes
Parish Mfg. Corporation

Distributors, Ignition, B16
*Atwater Kent Mfg. Co.
*North East Electric Co.

Drive, Starting Motor
Eclipse Machine Co.

Drop-Forgings
Canton Drop Forging & Mfg. Co.
General Drop Forge Co.
Park Drop Forge Co.
Williams & Co., J. H.
Wyman-Gordon Co.

Engines, Marine**
Wisconsin Motor Mfg. Co.

Engines, Motor Truck**
*Continental Motors Corporation
*Light Mfg. & Foundry Co.
Wisconsin Motor Mfg. Co.

Engines, Passenger Car**
*Continental Motors Corporation
*Light Mfg. & Foundry Co.
Wisconsin Motor Mfg. Co.

Engines, Tractor**
*Continental Motors Corporation
*Light Mfg. & Foundry Co.
Wisconsin Motor Mfg. Co.

Equipment, Foundry
Standard Pattern Works of Detroit, Inc.

Facings, Clutch
Johns-Manville, Inc.
Thermoid Rubber Co.
Raybestos Co.

Fans, Radiator
Sparks-Withington Co.

Fasteners, Hood
Eberhard Mfg. Co.

Felt
American Felt Co.

Felloe-Bands, Motor-Truck, Pneumatic Tire, G4
*Motor Wheel Corporation

Fenders
Parish Mfg. Corporation

Fibre, Vulcanized
American Vulcanized Fibre Co.

Flanges, Hub
Crosby Co.
Parish & Bingham Corporation
Smith Corporation, A. O.

Flow-Meters
Penberthy Injector Co.

Forgings, Brass
Scovill Mfg. Co.

Forgings, Drop (See Drop-Forgings)

Frames, Pressed Steel
Detroit Pressed Steel Co.
Parish & Bingham Corporation
Parish Mfg. Corporation
Sharon Pressed Steel Co.
Smith Corporation, A. O.

Frames, Rolled Section
Mansfield Steel Corporation

Fuel-Feed Systems
Sparks-Withington Co.

Fuses, Electric, B32
*Johns-Manville, Inc.

Gages, Gasoline
Penberthy Injector Co.
Nagel Electric Co., W. G.

Gages, Oil, B12
*Nagel Electric Co., W. G.

Gages, Tire Pressure
Schrader's Son, Inc., A.

Gasoline
Texas Co.

Gears, Bevel
Link-Belt Co.

Gears, Spur
Link-Belt Co.

Gears, Transmission
Canton Drop Forging & Mfg. Co.
Link-Belt Co.
Wyman-Gordon Co.

Gears, Worm
Link-Belt Co.

Generators, Battery Charging (Electric Vehicle)
Westinghouse Electric & Mfg. Co.

Generators (Bracket Mounting, B18)
*Atwater Kent Mfg. Co.
*North East Electric Co.
Westinghouse Electric & Mfg. Co.

Generators (Flange Mounting, B17)
*Atwater Kent Mfg. Co.
*North East Electric Co.
Westinghouse Electric & Mfg. Co.

Graphite
Dixon Crucible Co., Jos.

Greases, Cup and Gear
Dixon Crucible Co., Jos.
Texas Co.

Grease-Cups, C57
*Link-Belt Co.

Guards, Radiator
Mansfield Steel Corporation

Handles, Machine-Tool
Williams & Co., J. H.

Hardware, Body
Soss Mfg. Co.

Heaters, Passenger-Car Body
Perfection Heater & Mfg. Co.

Hinges, Door
Eberhard Mfg. Co.

Hinges, Windshield
Eberhard Mfg. Co.

Hitches, Trailer, K42
*Mansfield Steel Corporation

Hoists, Power and Hand
Mansfield Steel Corporation

Holders, Tool
Williams & Co., J. H.

Hooks, Towing
Mansfield Steel Corporation

Horns, Hand
E. A. Laboratories, Inc.

Horns, Motor-Driven
E. A. Laboratories, Inc.
North East Electric Co.
Sparks-Withington Co.

Hose, Gasoline
Thermoid Rubber Co.

Hose, Radiator, C51
*Thermoid Rubber Co.

Housings, Axle
Crosby Co.
Parish & Bingham Corporation
Parish Mfg. Corporation
Sharon Pressed Steel Co.
Smith Corporation, A. O.

Hubs, Wheel
Smith Corporation, A. O.

Ignition-Generators
North East Electric Co.

Instruments, Vibration, Indicating and Recording
Vibration Specialty Co.

Insulation, Molded
American Insulator Corporation
General Bakelite Co.

Jacks, Wheel
Arrow Grip Mfg. Co., Inc.

Jars, Storage Battery, B39
*Marko & Co., Inc., Paul M.

Keys, Woodruff
Whitney Mfg. Co.

Keys, Spring
Williams & Co., J. H.

Levers, Brake
Ford Mfg. Co., M. J.

Lining, Brake, C55
*Johns-Manville, Inc.
*Raybestos Co.
*Thermoid Rubber Co.

Locks, Automobile
Karlok Mfg. Co.

Lubricants, D65
Dixon Crucible Co., Jos.
Texas Co.

Lubricating Systems
Bowen Products Corporation

Machines, Balancing
Olsen Testing Machine Co., Tinius Vibration Specialty Co.

Machines, Power Transmission
Link-Belt Co.

Machines, Testing
Olsen Testing Machine Co., Tinius

Magnetos, B14
*Scintilla Magneto Co., Inc.
*Teagle Co.

Molybdenum, Metallic
Vanadium Corporation of America

Motors, Electric Vehicle
Westinghouse Electric & Mfg. Co.

Motors (See Engines)

Motors, Starting (See Starting Motors)

Mufflers, Carbureter
Maxim Silencer Co.

Mufflers, Engine
Maxim Silencer Co.

Mufflers, Heater
Maxim Silencer Co.

Nails
Interstate Iron & Steel Co.

Nuts, Thumb
Williams & Co., J. H.

Odometers, Hub, F2
*Johns-Manville Co., Inc.

Oil-Pans, Engine
Sharon Pressed Steel Co.

Oils (See Lubricants)

Packing, Asbestos and Fibrous
Johns-Manville, Inc.

Pads, Pedal
Auto Pedal Pad Co.

Pads, Accelerator
Auto Pedal Pad Co.

Paints
Dixon Crucible Co., Jos.

Parts, Pressed Steel (See Stampings)

Patterns, Wood and Metal
Standard Pattern Works of Detroit, Inc.

Pedals, Extension
Auto Pedal Pad Co.

Pencils, Drawing
American Lead Pencil Co.
Dixon Crucible Co., Jos.

Pins, Cotter, C7
*Ford Mfg. Co., M. J.
*Williams & Co., J. H.

Pins, Rod-End, C10
*Ford Mfg. Co., M. J.
*Steel Products Co.

Piston-Rings (for Standard Piston-Ring Grooves, A6)
*Ever-Tyte Piston Ring Division

Power Take-Offs, E1
Brown-Lipe Gear Co.

Primers, Engine
Master Primer Co.

Products, Screw-Machine
Link-Belt Co.
Rich Tool Co.
Scovill Mfg. Co.

Radiators**
*G & O Mfg. Co.
*Long Mfg. Co.
Sparks-Withington Co.
United States Cartridge Co.

Re-Vaporizers, Gasoline
Penberthy Injector Co.

Rectifiers, Battery Charging
Westinghouse Electric & Mfg. Co.

Relays, Cut-Out
North East Electric Co.

Retainers, Ball
Bearings Co. of America

Rims, Pneumatic Tire, G1
*Motor Wheel Corporation

Rivets, Steel
Interstate Iron & Steel Co.

Rivets, Brass and Copper
Rome Brass & Copper Co.
Scovill Mfg. Co.

Rod-Ends, C8
Eberhard Mfg. Co.
*Ford Mfg. Co., M. J.
*Steel Products Co.

Rods, Brass, C57b and D57c
*Rome Brass & Copper Co.
*Scovill Mfg. Co.

Rods, Bronze and Copper
Rome Brass & Copper Co.

Rods, Fibre
American Vulcanized Fibre Co.

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Running-Boards
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Parish Mfg. Corporation
Sharon Pressed Steel Co.
Smith Corporation, A. O.

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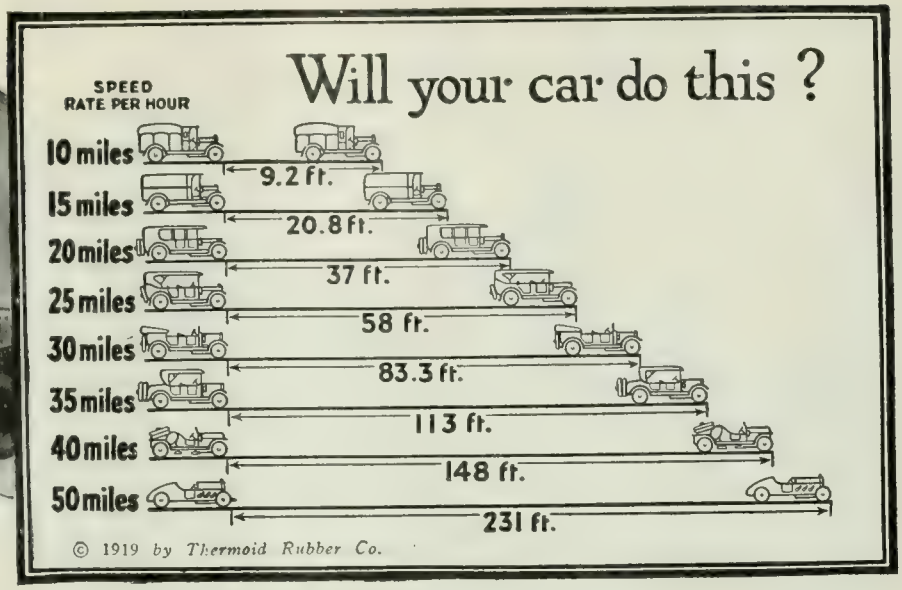


Famous Thermoid Standard Chart of stopping distances, now approved by Police Officials and Automotive Engineers. Chart shows distance in which car should stop if brakes are efficient. Brakes lined with Thermoid meet these standards

2 out of 3 motor accidents

occur under 15 *miles an hour*

TWO out of three of those wrecked cars you see along the road were smashed when they were going *slowly*. Statistics show that out of the nearly 600,000 motor accidents of last year, approximately 65% occurred at fifteen miles an hour —or less.

Safety isn't a matter of speed, but of the ability to stop. The chart above shows how quickly efficient brakes should be able to stop a car.

The essential factor of dependable brakes is good brake lining. Ordinary woven lining wears down quickly and unevenly. It requires frequent adjustments to keep the car within safety limits.

40% more material—hydraulic compressed

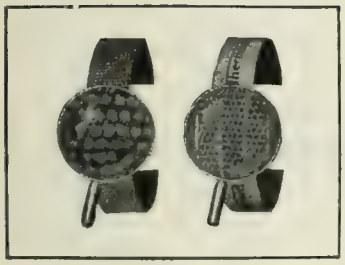
To insure efficient brake action at all times, Thermoid Hydraulic Compressed Brake Lining has been perfected. It maintains its gripping power even when worn as thin as cardboard.

In each square inch of Thermoid there is *40% more material* than in ordinary lining. This additional body gives a closer texture, which is made tight and compact by *hydraulic compression* of 2,000 pounds. By an exclusive process — *Grapnalizing*— Thermoid is made to resist moisture, oil and gasoline.

Because of its unfailing efficiency, the manufacturers of 50 of the leading cars and trucks use Thermoid.

Send for "The Dangers of Faulty Brakes." It contains valuable information which every engineer should know.

THERMOID RUBBER COMPANY
Factory and Main Offices: Trenton, New Jersey
New York, Chicago, San Francisco, Detroit, Atlanta, Boston, Cleveland, London, Paris, Turin



Ordinary woven lining
Notice the loosely woven texture.
Wears down quickly and unevenly.
Loses its gripping power as it wears.

Thermoid Brake Lining
Hydraulic Compressed.
Notice the compact texture.
Wears down slowly.
Gives uniform gripping surface until worn wafer-thin.

Thermoid Brake Lining

Hydraulic Compressed

Makers of "Thermoid-Hardy Universal Joints" and "Thermoid Crolide Compound Tires"

SOURCES OF SUPPLIES

Screws, Cap, C1
*Scovill Mfg. Co.
*Steel Products Co.

Screws, Thumb
Williams & Co., J. H.

Shaft-Ends, C14
*Brown-Lipe Gear Co.

Shapes (Extruded), Brass, Bronze and Copper
Rome Brass & Copper Co.

Shapes (Rolled), Brass, Bronze and Copper
Rome Brass & Copper Co.

Sheets, Brass, D56
*Scovill Mfg. Co.

Sheets, Brass, Bronze and Copper
Rome Brass & Copper Co.

Sheets, Fibre
American Vulcanized Fibre Co.

Shims, Laminated
Laminated Shim Co., Inc.

Sills, Body
Smith Corporation, A. O.

Speedometers
Johns-Manville, Inc.

Spokes, Wood, Motor Truck, F1
*Motor Wheel Corporation

Spokes, Wood, Passenger Car, F1a
*Motor Wheel Corporation

Springs, Coiled
Gibson Co., Wm. D.

Springs, Flat
Gibson Co., Wm. D.

Sprockets, Roller-Chain, E4
*Baldwin Chain & Mfg. Co.
*Link-Belt Co.
Morse Chain Co.
*Whitney Mfg. Co.

Sprockets, Silent-Chain
Morse Chain Co.
Whitney Mfg. Co.
Link-Belt Co.

Stabilizers
Watson Co., John Warren

Stampings
Crosby Co.
Parish & Bingham Corporation
Parish Mfg. Corporation
Smith Corporation, A. O.
Soss Mfg. Co.

Starter-Generators
North East Electric Co.

Starting Motors (Flange Mounting), B19
*Atwater Kent Mfg. Co.
*North East Electric Co.
Westinghouse Electric & Mfg. Co.

Starting Motors (Sleeve Mounting), B20
*Atwater Kent Mfg. Co.
*North East Electric Co.
Westinghouse Electric & Mfg. Co.

Starting, Automatic Meshing Drive for
Eclipse Machine Co.

Steel, Alumino-Vanadium
Vanadium Corporation of America

Steel, Chromium, D10
*Central Steel Co.
*Interstate Iron & Steel Co.

Steel, Chromium-Vanadium, D11
*Central Steel Co.
*Interstate Iron & Steel Co.

Steel, Cupro-Vanadium
Vanadium Corporation of America

Steel, Ferro-Molybdenum
Vanadium Corporation of America

Steel, Ferro-Tungsten
Vanadium Corporation of America

Steel, Ferro-Vanadium
Vanadium Corporation of America

Steel, Molybdenum
Interstate Iron & Steel Co.

Steel, Nickel, D9
*Central Steel Co.
*Interstate Iron & Steel Co.

Steel, Nickel-Chromium, D10
*Central Steel Co.
*Interstate Iron & Steel Co.

Steel, Silico-Manganese, D11
*Central Steel Co.
*Interstate Iron & Steel Co.

Strips, Brass, Bronze and Copper
Rome Brass & Copper Co.

Superheat System, Gasoline
Deppé Motors Corporation

Switches, Lighting
Westinghouse Electric & Mfg. Co.

Switches, Starting
North East Electric Co.
Westinghouse Electric & Mfg. Co.

Tacks
Interstate Iron & Steel Co.

Tachometers (with Standard Drive), C75
*Johns-Manville, Inc.

Tape, Insulated
Johns-Manville, Inc.

Tires, Pneumatic, G1
*Thermoid Rubber Co.

Tools, Machine Cutting
Haynes Stellite Co.

Torque-Arms
Sharon Pressed Steel Co.
Smith Corporation, A. O.

Tractors, Industrial
Baker R & L Co.

Trailers
Sharon Pressed Steel Co.

Transmissions**
*Brown-Lipe Gear Co.
Light Mfg. & Foundry Co.

Trucks, Industrial
Baker R & L Co.

Tubing, Brass, D57d
Rome Brass & Copper Co.
*Scovill Mfg. Co.
United States Cartridge Co.

Tubing, Copper, D57e
Rome Brass & Copper Co.
*Scovill Mfg. Co.
United States Cartridge Co.

Tubing (Tapered), Brass Bronze and Copper
Rome Brass & Copper Co.

Tubing, Fibre
American Vulcanized Fibre Co.

Tubing, Flexible Metal
Titeflex Metal Hose Corporation

Tubing, Rubber
Thermoid Rubber Co.

Tubing, Steel, D47
Smith Corporation, A. O.

Tungsten, Metallic
Vanadium Corporation of America

Univeral-Joints, E6
*Thermoid Rubber Co.

Valve-Lifters
Rich Tool Co.

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*Rich Tool Co.
*Steel Products Co.

Valves, Tire
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Vaporizers (See Primers)

Voltmeters, B12
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Washers, Fibre
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Washers, Steel
Interstate Iron & Steel Co.

Wheels, Pressed Steel
Disteel Wheel Corporation

Wheels, Wood
Motor Wheel Corporation
Muncie Wheel Co.

Wicks, Felt
American Felt Co.

Wire (See Cable, Insulated)

Wire, Magnet
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Wire Products
Interstate Iron & Steel Co.

Wrenches
Williams & Co., J. H.

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Twelve Advantages of Standardization

DESIGNING

(1) Simplifies General Design Work
(2) Proven Engineering Practice Assured

MANUFACTURING

(3) Number of Sizes Reduced to the Desirable Minimum
(4) Production Costs of Many Parts Reduced Because of { Longer Production Runs; Reduced Tool Costs; Overhead Per Piece Reduced }
(5) Inventories are Reduced
(6) Sources of Supplies are Increased

MARKETING

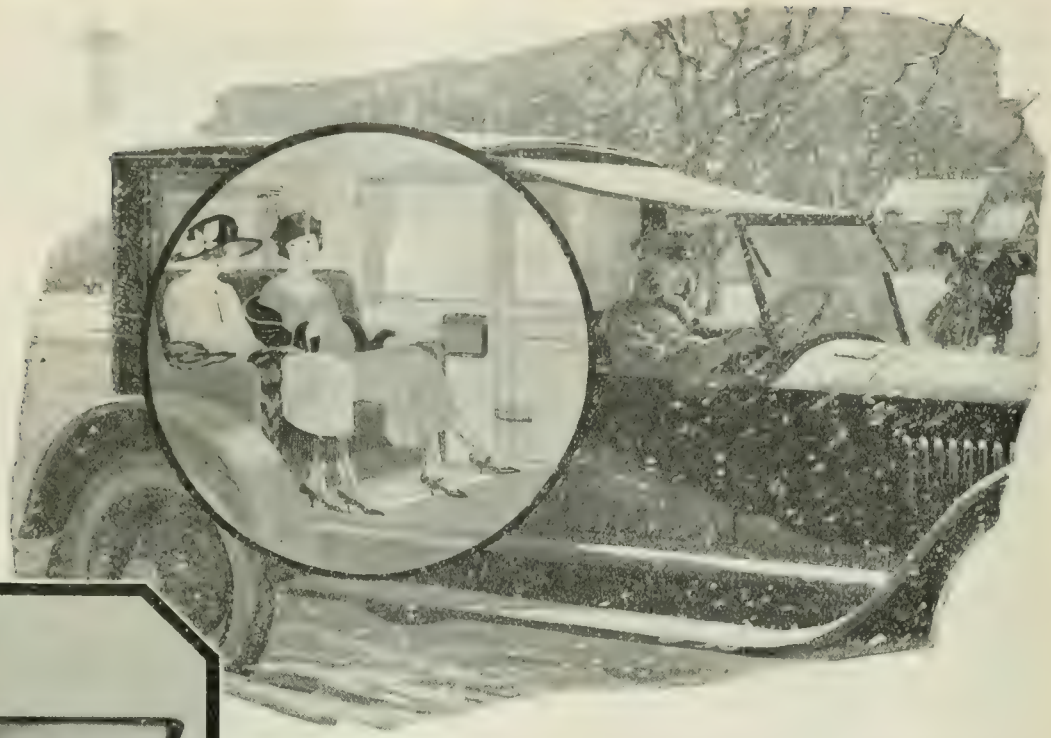
(7) Competition is Encouraged
(8) Larger Export Business is Made Possible

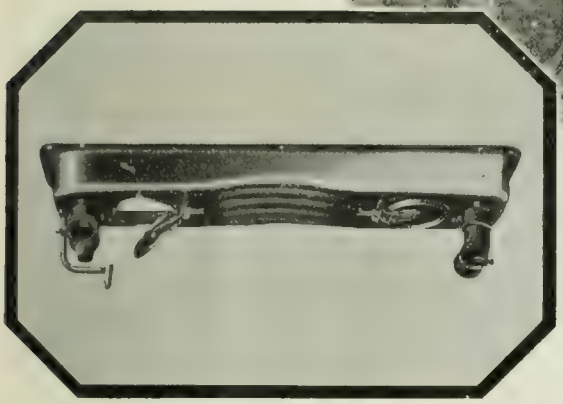
OPERATING

(9) Service is Simplified
(10) Less Time "Out-of-Service"

SERVICING

(11) Repair-Parts Stock Reduced
(12) Replacements Facilitated





Perfection flush floor type heater pan showing clean-out doors.

Perfection Heater Talks

By Clyde S. Pelton, M. S. A. E.

Clean-out Doors in Heater Pan

This may seem a small detail, but unusual attention to apparently small details has made Perfection Heaters as universally satisfactory and popular as they are.

So that the heater casing or pan which is used on flush floor type heaters, may be kept clean, and to prevent unpleasant odors which might arise from gathered refuse in the heater pan, trap-doors have been provided.

A glance at the illustration will show the care that is used in designing even so small a detail of Perfection Motor Car Heaters.

These trap-doors are rattle proof, are easily opened, will not stick with mud or rust and are properly located to provide the greatest facility in cleaning.

The Perfection Heater & Manufacturing Co.,
6545 Carnegie Ave., Cleveland, O.

PERFECTION
MOTOR CAR
HEATERS

52 Leading Motor Car Manufacturers Use Perfection Heaters as a Standard Equipment

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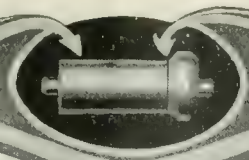
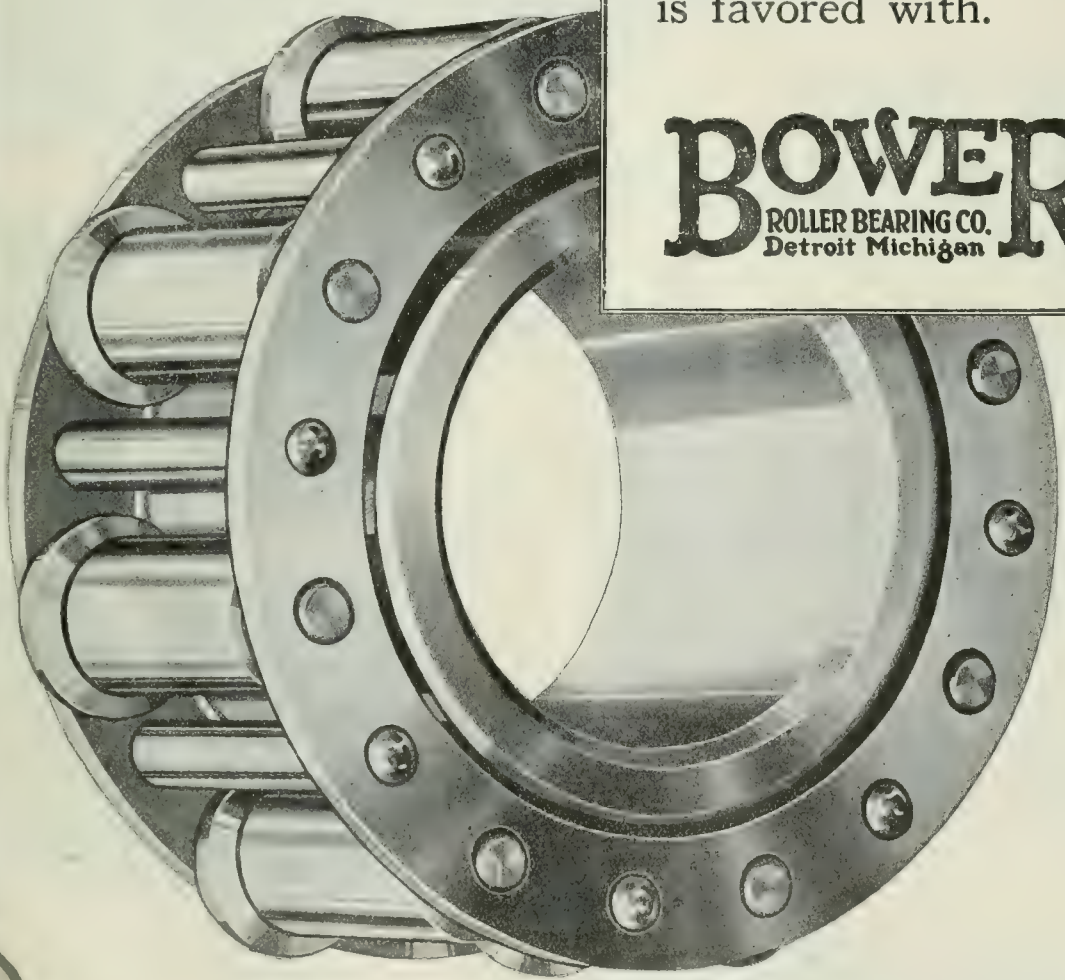
CARRIES THE LOAD



TAKES THE THRUST

BOWER Roller Bearings in a Car speaks volumes for the engineering care that particular car is favored with.

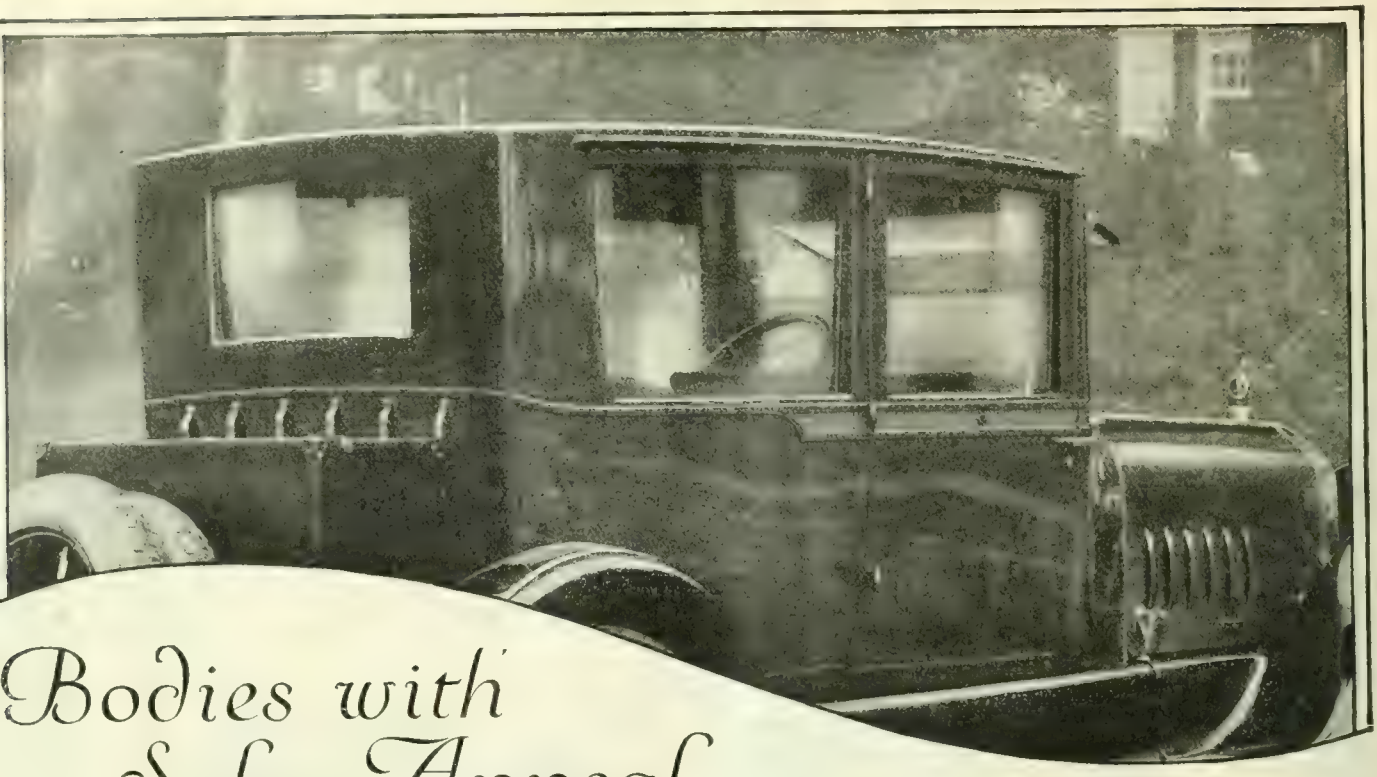
BOWER
ROLLER BEARING CO.
Detroit Michigan



Exclusive Bower Features

Separate bearing surfaces for load and thrust. Parallel raceways. Self-aligning. Never need adjusting. Does not develop end thrust under loads. Will not bind or end-slip.

BOWER SAVES POWER

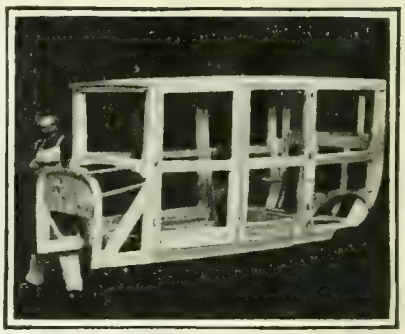


Bodies with Sales Appeal

For the next six months fully three-fourths of all automobiles sold will be closed cars.

Everyone of these will be selected largely from the appeal the body makes to the customer. The body equipment is of greater importance than all other selling features combined.

Raulang Bodies are nationally known and have a high prestige, gained in years of the finest coach building, with which to make such appeal



Raulang TRADE MARK AUTOMOBILE BODIES

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